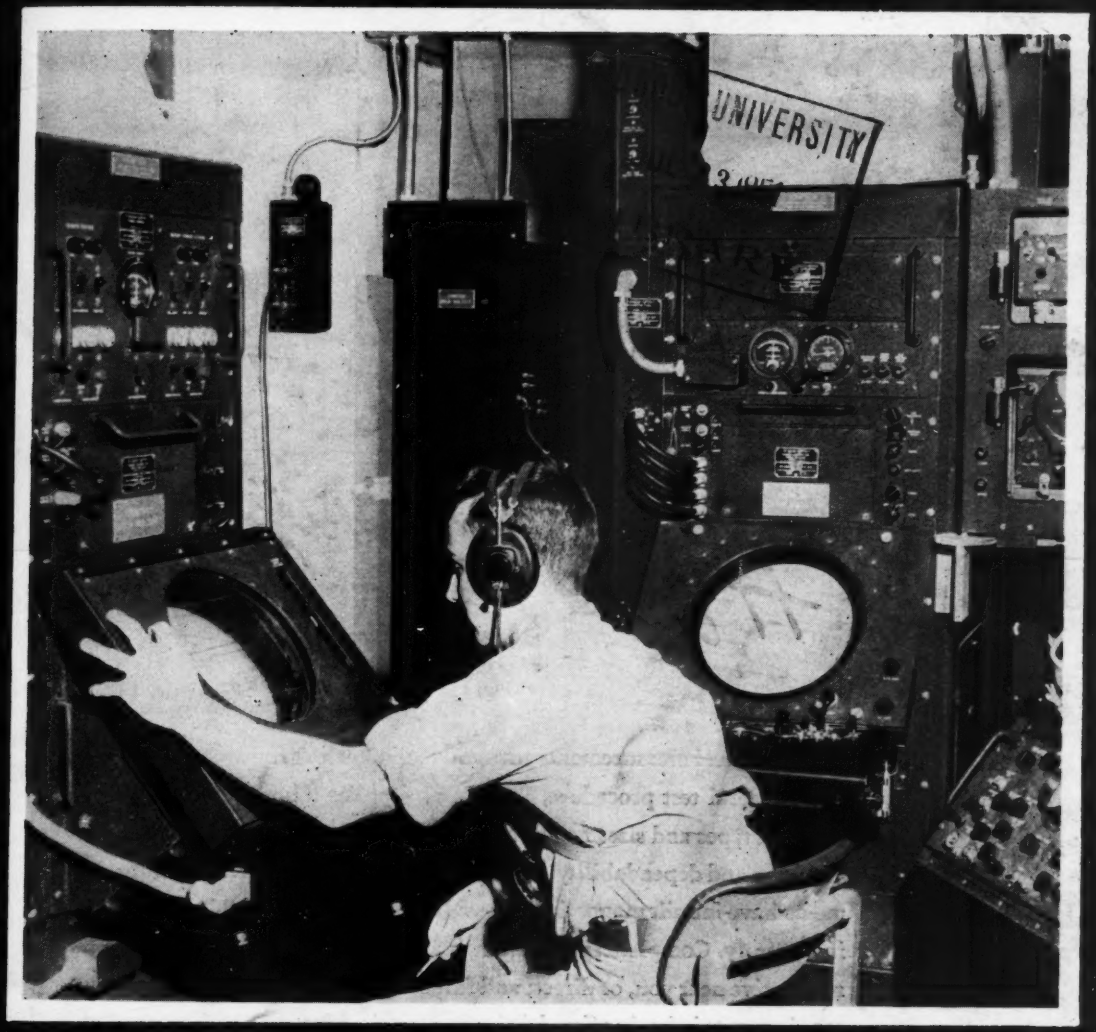
Instruments

THE MAGAZINE of MEASUREMENT and CONTROL

Vol. 24 | JULY 1951 | No. 7

INCLUDING THE *Journal of the Instrument Society of America*

AND THE *Journal of the Southern California Meter Association*

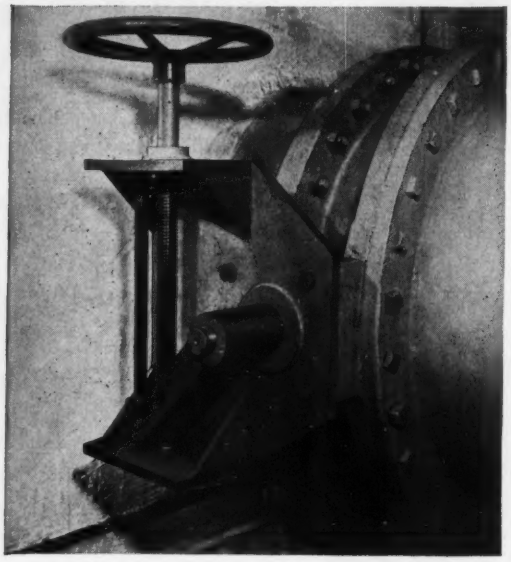


Instruments for "talking down" an aircraft to a safe landing under conditions of poor visibility. **See story on page 730.**

(Photo courtesy U. S. Navy and Bendix Radio)

R-S valvEvents

• EXCERPTS FROM THE R-S BOOK OF EXPERIENCE •



RUGGED Simplicity

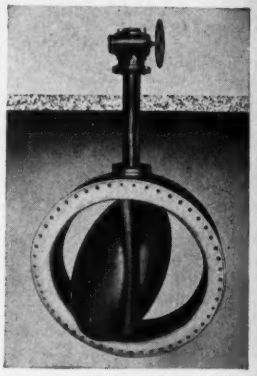
Correctly engineered mechanically and metallurgically, all body assemblies of R-S Valves equal or exceed A. S. A. standards in every detail. These valves are designed and constructed for rugged service and provided with such safety factors that they will exceed service expectations as well as reduce pumping and blower costs.

Consider also the few working parts, greater control rangeability, the self-cleaning feature and the fact that R-S Valves are readily adapted to automatic operation. Know the rugged simplicity of R-S Valves, and get the most from your valve investment.

District offices are listed in telephone directories as, "R-S Products Corp'n Valves".

R-S PRODUCTS CORPORATION
4600 Germantown Avenue, Philadelphia 44, Pa.
An S. Morgan Smith Company Subsidiary

No. 782—Heavy Duty Rubber Seated Wafer Type Valve with 5° angle seated vane and enclosed gear reduction drive. Gland can be removed and stuffing box repacked without removing prime mover.



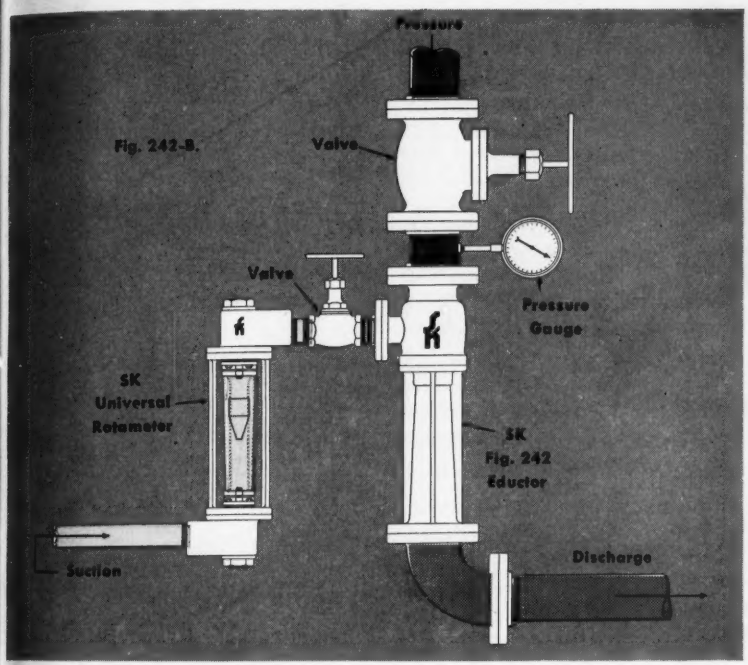
No. 739-740—Sixty-inch, 50-pound Heavy Duty Valve with gear reduction drive and handwheel for handling water at 40 psig. Vertical valve stem enclosed in steel pipe support. Thrust bearing absorbs vertical load.

No. 730—R-S Heavy Duty Floor Stand for rugged service in connection with any standard R-S handwheel operated valve.

No. 767—A 3-Way Valve (Two 24-inch 125-pound Cast Iron Valves bolted to 125-pound American Standard Tee). Electric motor operated by cross linkage. Automatic declutching handwheel for emergency operation.

News

HERE'S AN EASY WAY TO MEASURE AND MIX LIQUIDS INTO CONTINUOUS STREAMS



THE SYSTEM above is simplicity itself. It consists of a SK Rotameter and a SK Jet Eductor. It represents only one of numerous possible variations. With this system, you can mix two liquids in desired proportion in one continuous operation.

Flow of the pressure liquid is controlled by a valve and the orifice of the eductor nozzle. The pressure liquid passes through the eductor nozzle with sufficient velocity to draw in and entrain the suction liquid. Rate of flow of the suction liquid is measured by the Rotameter and controlled by a valve in the suction line. Both liquids are intimately mixed within the eductor to a degree not obtainable with most other types of mixing apparatus and are discharged through the discharge line. The mixing ratio remains constant as long as the pressures are held constant.

Of importance is the fact that the eductor has no moving parts—the Rotameter but one, the rotor. Maintenance, therefore, is low. Operation is consistently efficient. In addition, the eductor can be made of special materials to handle corrosive liquids.

The system is flexible. Additional liquids can be mixed by extending the system. SK Controlling Rotameters can be used in pressure and suction lines to proportion flows under changing conditions.

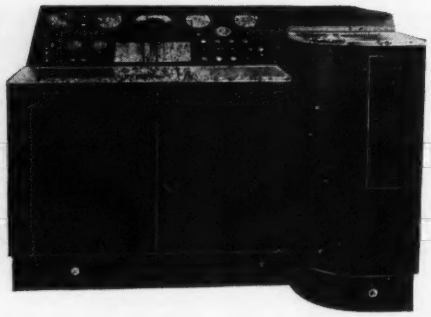
The SK Rotameter illustrated is a stock item, immediately available. SK Jet Eductors are built to meet job requirements. For details on the many types of Jet Eductors, request Bulletin 2-M. For information on all types of Rotameters, request Bulletin 18-RA. We'll send you either or both, promptly.

↑ At International Harvester Company's West Pullman Works, SK Rotameters, mounted on panels as shown in the photo, are used for test checking carburetors of various engines made by the company. The carburetors are installed in snap-jigs and are tested at low and wide-open flow—which corresponds to idling and full-speed operation. The Rotameters are used to check the air and fuel consumption. Since this is a production operation involving the checking of thousands of carburetors, instruments which indicate almost instantly were necessary. The SK Rotameters, after installation, met all specifications for both speed and accuracy. *For information on SK Universal Rotameters for panel mounting, request Bulletin* 18-*RB.*

SK Flow Indicators, designed to permit visual inspection of flow in a pipe line, can prevent damage to expensive equipment by indicating to observer whether or not a fluid is flowing. For information on the many types and sizes of SK Flow Indicators available, request Bulletin 18-W.

Manufacturing Engineers

Specify
CONTROL
PANELS
by
FALSTROM



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☐ CHEMICAL BOARDS
☐ GAGE BOARDS
☐ CONTROL CENTERS

Instruments
THE MAGAZINE OF
Measurement
and Control

Vol. 24 JULY 1951 No. 7

A NEW SERIAL

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JOURNAL of the
SOUTHERN CALIFORNIA METER ASSOCIATION

Measurement of Flow of Fluids through Orifice Meters 817
By William L. Cowan

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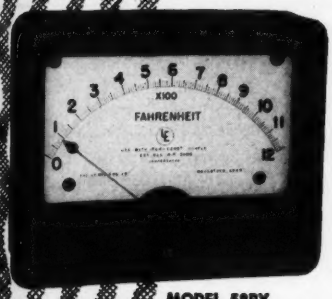
LEWIS INDICATING PYROMETERS

FOR TEMPERATURE TESTING IN THE LABORATORY OR IN THE PLANE . . .

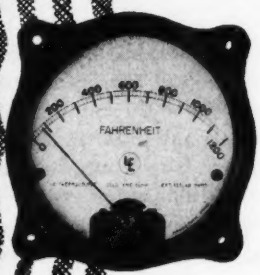
Constructed with the same care as our aircraft temperature indicators, these pyrometers bring "aircraft quality" to the test engineer. Use Lewis leads, thermocouples and selector switches to build complete temperature measuring installations. All models available with blank dials and white markings for photographic observers.



MODEL 58PY

This instrument has been used extensively by the leading motor-car manufacturers for road testing on the "Proving Grounds" — where performance counts. Housed in a rectangular bakelite case, this reliable, fully compensated pyrometer is furnished with 6 in. hand drawn scales for greater accuracy. The Model 58PY is available for use with all standard thermocouple materials, in many ranges to suit the most exacting application.

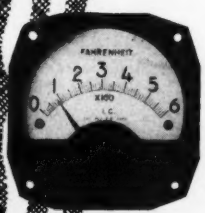
Accuracy — 1% of total scale deflection



MODEL 23B

Manufactured with the same type of movement as our aircraft pyrometers, the Model 23B pyrometer is well suited for use in moving vehicles and has been successfully used in many test stand installations. It is housed in a 4 in. round bakelite case that is flanged for panel mounting, and is available in several ranges for use with various thermocouple materials.

Accuracy — 2% of total scale deflection



MODEL 20B

The Model 20B series of indicators are patterned after our standard aircraft instruments and are supplied with 3" round steel cases suitable for panel installation. These compact, sturdy indicators have 2½ in. scales, are fully cold-end compensated and are available in many ranges for use with various thermocouple materials.

Accuracy — 2% of total scale deflection

STANDARD RANGES, ALL MODELS

FAHRENHEIT		*CENTIGRADE*	
0 to 400	0 to 1200	0 to 200	0 to 600
0 to 600	0 to 1600	0 to 300	0 to 800
0 to 800	0 to 1800	0 to 400	0 to 1000
0 to 1000	0 to 2000	0 to 500	0 to 1100
0 to 2500		0 to 1400	

THE LEWIS ENGINEERING CO.

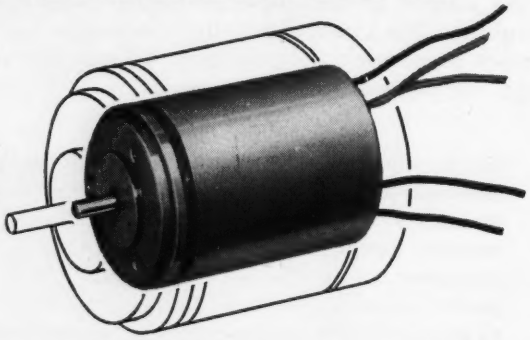
Manufacturers of *Complete* Temperature Measuring Systems for Aircraft

NAUGATUCK, CONNECTICUT

ECLIPSE-PIONEER

Announces the New Line of

PYGMY SYNCHROS



Size of pygmy as compared to AY-200 series outline

Eclipse-Pioneer has added a tiny new member to its great family of famous Autosyn* synchros. It's the new AY-500 series, a precision-built pygmy weighing only 1¾ oz. while scaling only 1.278" long and .937" in diameter (the same diameter, incidentally, as a twenty-five cent piece). Its accuracy and dependability are assured, thanks to Eclipse-Pioneer's 17 years of experience and leadership in the development of high precision synchros for aircraft, marine and industrial applications. For more detailed information on the AY-500 and other E-P Autosyns, such as the remarkably accurate AY-200 series (guaranteed accuracy to within 15 minutes on all production units), please write direct to Eclipse-Pioneer, Teterboro, N. J.

*REG. TRADE MARK BENDIX AVIATION CORPORATION

LOOK FOR THE PIONEER MARK OF QUALITY
REG. U.S. PAT. OFF.

Typical Performance Characteristics

	One AY-201-3 Driving		One AY-500-3 Driving
	One AY-500-3 Control Transformer	Two AY-500-3 Control Transformer	One AY-500-3 Control Transformer
INPUT			
Voltage	26-volts, single-phase	26-volts, single-phase	26-volts, single-phase
Frequency	400 cycles	400 cycles	400 cycles
Current	88 milliamperes	110 milliamperes	55 milliamperes
Power	0.8 watts	1.2 watts	0.9 watts
Impedance	105+j280 ohms	100+j220 ohms	290+j370 ohms
OUTPUT			
Voltage Max. (rotor output)	17.9 volts	16.2 volts	14.1 volts
Voltage at null	40 millivolts	40 millivolts	40 millivolts
Sensitivity	310 millivolts/degree	280 millivolts/degree	245 millivolts/degree
Voltage phase shift	23 degrees	26 degrees	44 degrees
System accuracy (max. possible spread)	0.6 degrees	0.6 degrees	0.75 degrees

Other E-P precision components for servo mechanism and computing equipment:

Servo motors and systems • rate generators • gyros • stabilization equipment • turbine power supplies • remote indicating-transmitting systems and special purpose electron tubes.

For detailed information, write to Dept. A

ECLIPSE-PIONEER DIVISION of

TETERBORO, NEW JERSEY

Bendix AVIATION CORPORATION

Export Sales: Bendix International Division, 72 Fifth Avenue, New York 11, N. Y.

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COVER STORY

Ground-controlled Approach (GCA) is a radar system which helps bring any type aircraft to a safe landing under conditions of poor visibility —without the use of special instruments in the plane itself. In the GCA system, the plane on approach is tracked by precision radar, which determines the elevation, azimuth, and range of the plane. These data are compared electronically with the "Ideal Glide Path," and the amount of deviation is displayed on elevation and azimuth error indicators, calibrated in feet. An Approach Controller, who watches the indicators, "talks down" the pilot.

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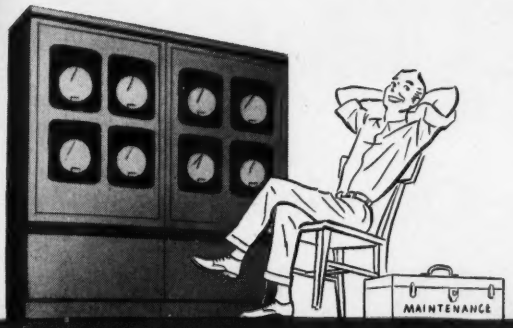
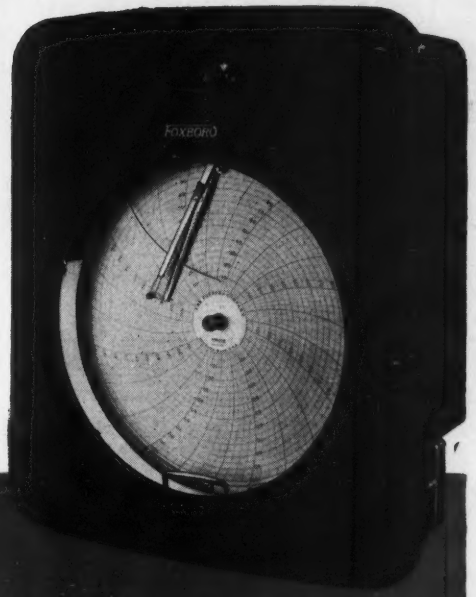




DYNALOGS* have

No slidewire • No Balancing Motor • No Batteries to standardize

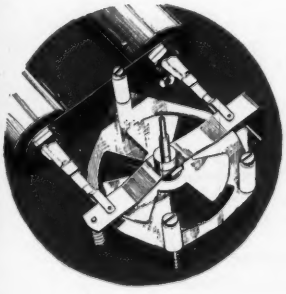
PRACTICALLY NO MAINTENANCE

With Dynalog Recorders and Controllers, maintenance men are freed from hazards of sticking electrical contacts and worn slidewires . . . freed from routine lubrication and cleaning of balancing motors, periodic standardizing and replacement of batteries. No wonder maintenance men breathe easier!

The simplicity of Dynalog design is one reason for its unequalled freedom from maintenance. In the entire balancing mechanism there are only four moving parts (none moving faster than the pen). It's free from the gears, cables, etc. used in conventional bridge-type instruments . . . the result of advanced engineering from concept to construction.

Freedom from maintenance is only one of many important advantages of Dynalog Instruments. They offer . . . *speed* that's full scale to new balance in as little as one second . . . *sensitivity*, one ten-thousandth of scale . . . *accuracy*, ¼ of 1% of scale. Available for measurement and control of temperature (with resistance bulbs or thermocouples), humidity, pressure, flow, force, pH, conductivity, etc. Get the complete story in Bulletin 427-1. Write **The Foxboro Company, 467 Neponset Ave., Foxboro, Mass., U.S.A.**

**Reg. U. S. Pat. Off.*



The heart of Dynalog superiority

It's a simple variable capacitor! Taking the place of the conventional slidewire, this important component gives Dynalog Instruments absolutely STEPLESS continuous balancing. It gives you an instrument of extreme accuracy and stability, with a sturdiness that withstands the most severe industrial conditions.

FOXBORO Reg. U. S. Pat. Off. **DYNALOG***

The electronic potentiometer that has NO SLIDEWIRE

Use the C_Q Method—

Evaluate All The Quality Factors
IN SELECTING CONTROL VALVES

"Quality" is only a word—which has no real number or scale; but, by definition, it implies comparison and by common usage it connotes high value.

The C_Q (Quality Coefficient) method sets a standard — which is necessarily also intangible but one which could, if you wished, be given an arbitrary numerical expression.

Our standard of design and manufacture is to build a control valve which, in the light of our extensive knowledge and experience, will live up to our definition of quality, i. e.:

"A high quality product provides accurate performance over a long period with a minimum of maintenance and operation delays."

Your standard in selecting control valves is undoubtedly very similar, based on your own experience.

We suggest your using the C_Q method in comparing control valves. Set a standard; evaluate *all* the quality factors in the valves considered. (As a reminder, a list of some of these is printed here.) The sum of all quality factors of a valve is its C_Q (Quality Coefficient). Then when you compare price, consider that the invoice figure is only the first cost — the real cost might be expressed

$$\text{Real Cost} = \frac{\text{Price}}{C_Q}$$

for you will agree that for the same investment, the higher the quality the lower the actual over-all cost.

Compare Masoneilan Control Valves with *any* others — use the C_Q Method.

Check For These Diaphragm Motor Quality Factors

Performance Factor

Effective Diaphragm Area
Stroke Length
Response to Air Pressure Changes
Stroke vs. Air Pressure Relationship
Guide Design for Minimum Friction

Mechanical Construction Factor

Diaphragm Case Air Pressure Rating
Diaphragm Case to Yoke Fastening
Rigidity and Strength of Yoke
Yoke Connection to Body Assembly
Strength of Spring Stem and Diaphragm Button Assembly
Size of Springs vs. Effective Area and Stroke of Motor
Diaphragm Design for Reproducible Stroke
Motor Guiding for Friction Free Operation

Convenience Factor

Provision for Mounting Instruments and/or Accessories
Adaptability to Air-to-Close or Air-to-Open Action
Provision for Various Types of Handwheels
Selection of Stroke and Spring Range

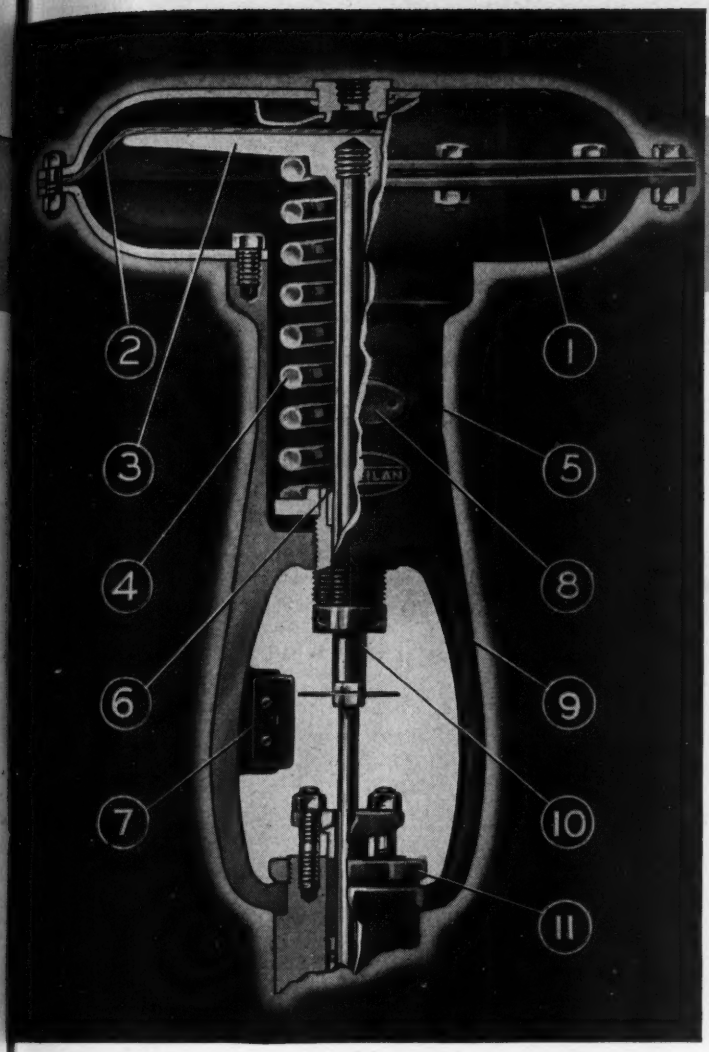
Maintenance Factor

Accessibility of Valve Stuffing Box
Convenience of Spring Adjustment

Appearance Factor

Low Over-all Height
Smooth External Contours
Compactness
Serial Plate Information
Travel Indicator Design
Ability to Withstand Rough Handling
Strength of Stem and Stem Connections
Protection of Spring and Diaphragm

See our Exhibit in Booths 214-216 at the Sixth National Instrument Exhibit, Sam Houston Coliseum, Houston, Texas, September 10-14, 1951.



For Example Consider the Diaphragm Motor of Masoneilan 10,000 Series Control Valves

1. **Steel Diaphragm Case** for high mechanical strength, lightness, high safety factor in case of severe over-pressuring. Parkerized inside and out for corrosion resistance. ¼" or ½" air connection fitting welded inside case for better appearance. Initial stop inside case establishes correct stroke with respect to diaphragm position. Through bolted construction for ease of disassembly — avoids moisture-collecting pockets which cause rusting. Permits use of flat stock diaphragms in emergency. Adapted to case-mounted handwheels. Provides for reverse-acting motors for valves with non-reversible plugs.

2. **Preformed Diaphragm** of rubber or neoprene with fabric insert — designed to provide maximum practical effective area throughout stroke. Provides frictionless self-aligning upper guide. Beaded edge adds insurance against leakage.

3. **Steel Diaphragm Button** — compact and strong — welded to spring stem, preventing possibility of disengagement in the event of excess line vibration.

4. **Heavy Springs** for low stress — prevents breakage and permanent set. Calibrated for 3-15 or 6-30 psi ranges. Japanned for corrosion resistance. Exterior adjustment for ease of setting spring initial — has ball thrust bearing on larger size valves.

5. **Cast Iron Yoke and Spring Barrel** have heavy cross-sections for rigidity and mechanical strength; will not deform in rough handling, causing misalignment. Inherently corrosion resistant. Inclosed spring barrel protects springs. Unusually large opening in yoke provides ease of access to stuffing box and positioner linkage — makes stroke scale easily readable. Yoke designed for side mounted handwheels.

6. **Oilite Bronze Lower Guide** together with self-aligning frictionless upper guide in diaphragm insures alignment, minimum friction.

7. **Stroke Scale** graduated in ⅛" of actual travel. Rated stroke marked on plate. Indicator index always at same position on spring stem — aids in stem adjustment on assembly.

8. **Mounting Pads** — front and rear, provide for mounting controller, positioner and/or air set.

9. **Serial Plate** has *full* valve specifications — materials, rating, spring range, direction of travel — even an etched picture of type and seating direction of plug.

10. **Large Diameter Spring Stems** for strength; direct threaded connection to valve stem without use of adapters; plus Keylock on sizes 3" up.

11. **Motor to Bonnet Connection** by means of heavy, large diameter, forged steel drive nut, for strength and true alignment.

THE MASONEILAN 10,000 SERIES CONTROL VALVE IS

A High C_Q Product

MASON-NEILAN REGULATOR CO.

1210 Adams Street, Boston 24, Mass., U. S. A.

Sales Offices or Distributors in the Following Cities

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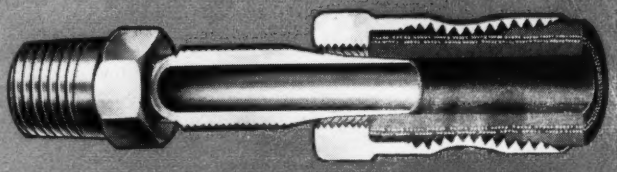
YOU CANNOT INSURE FULL C_V WITHOUT A HIGH C_Q

WEATHERHEAD

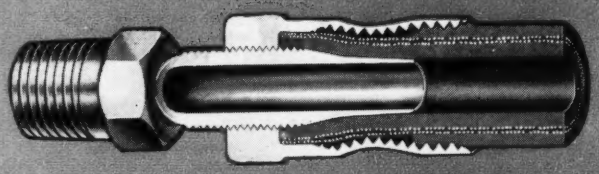
REUSABLE HOSE ENDS AND HEAVY-DUTY HOSE

permit quick make-up of flexible lines from stock

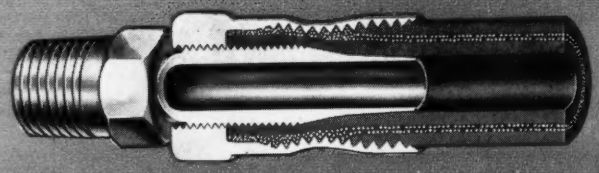
No longer need design changes make flexible hose line inventories obsolete. Make up what you need to any length to meet every pressure demand—from standard hose and *Weatherhead All-Steel REUSABLE HOSE ENDS.*



1. Hold hex of body (right) in vise. Turn hose into body (left-hand thread) until end of hose barely bottoms in end fitting.



2. Lubricate the insert (left) and the inside of the hose end with oil . . . thread insert into body.



3. Tighten the insert until the hex of the insert shoulders on the body. (Body has left-hand thread so that tightening effects seal both inside and outside of hose.)

Quick and easy—any length; meets every pressure demand; low, medium, medium-high and high. Figure for yourself the inventory savings when you simply stock random lengths of hose plus the proper sizes of REUSABLE ENDS.

WRITE FOR DETAILS—get new catalog No. H-1451A. Address The Weatherhead Company, Dept. S, 300 East 131st Street, Cleveland 8, Ohio.

FIRST IN HYDRAULIC CONNECTIONS

WEATHERHEAD

Plants at Cleveland, Ohio; Angola and Columbia City, Indiana; and St. Thomas, Ontario

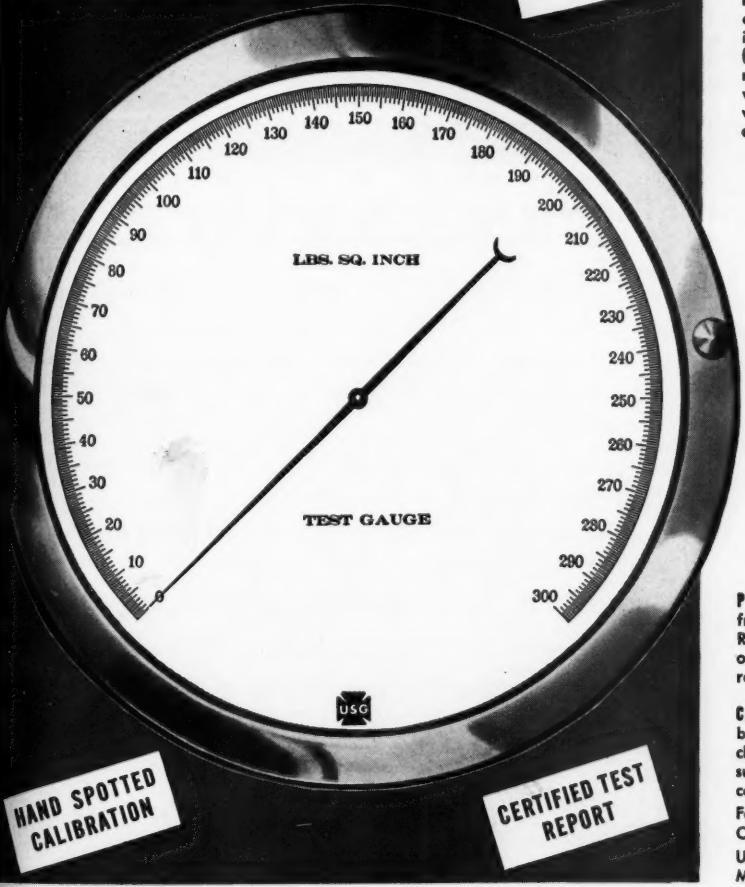
The Mark of Quality

"300,000 LB. CAPACITY RIEHLE COMPRESSION TESTING MACHINE, MADE BY RIEHLE TESTING MACHINE DIVISION OF AMERICAN MACHINE AND METALS, INC."

For Peak Precision

USG LABORATORY TEST GAUGES

Wherever you require *peak precision* from a gauge—for compression or tensile strength testing machines, or for replacing or supplementing dead weight testers or manometers—you can use the accuracy of USG Laboratory Test gauges to advantage.



PEAK PRECISION—½ of 1% of the indicated reading above 20% of the maximum dial range and one part in 500 (0.2%) below 20% of the maximum dial range. A Certified Test Report is furnished without charge for applying corrections when instrument is used at accuracies higher than ½ of 1% of indicated reading.

PRECISION DRAWN TUBE—Drawn from phosphor bronze, beryllium copper, or 403 stainless steel—depending on pressure range. All tubes are specially treated to produce minimum hysteresis and drift.

PRECISION MOVEMENT—Aircraft quality for highest sensitivity. Nickel-dipped bronze with extra long bearings and heavy bronze bushing fitted with nickel silver pinions and arbors.

PRECISION CALIBRATION—Graduations are individually hand-spotted and engraved on a white background. Dial may be rotated 10° for zero adjustment to compensate for preloading.

DIAL SIZES—12" and 16".

PRESSURE RANGES—All pressure ranges from 30" Vacuum and 15 to 20,000 p.s.i. Ranges over 30,000 p.s.i. on special order. Suppressed scales available on request.

CASE AND RING—Cast aluminum case, black finish. Cast brass ring with polished chromium finish. Flush panel mounting or surface mounting with back or lower connection.

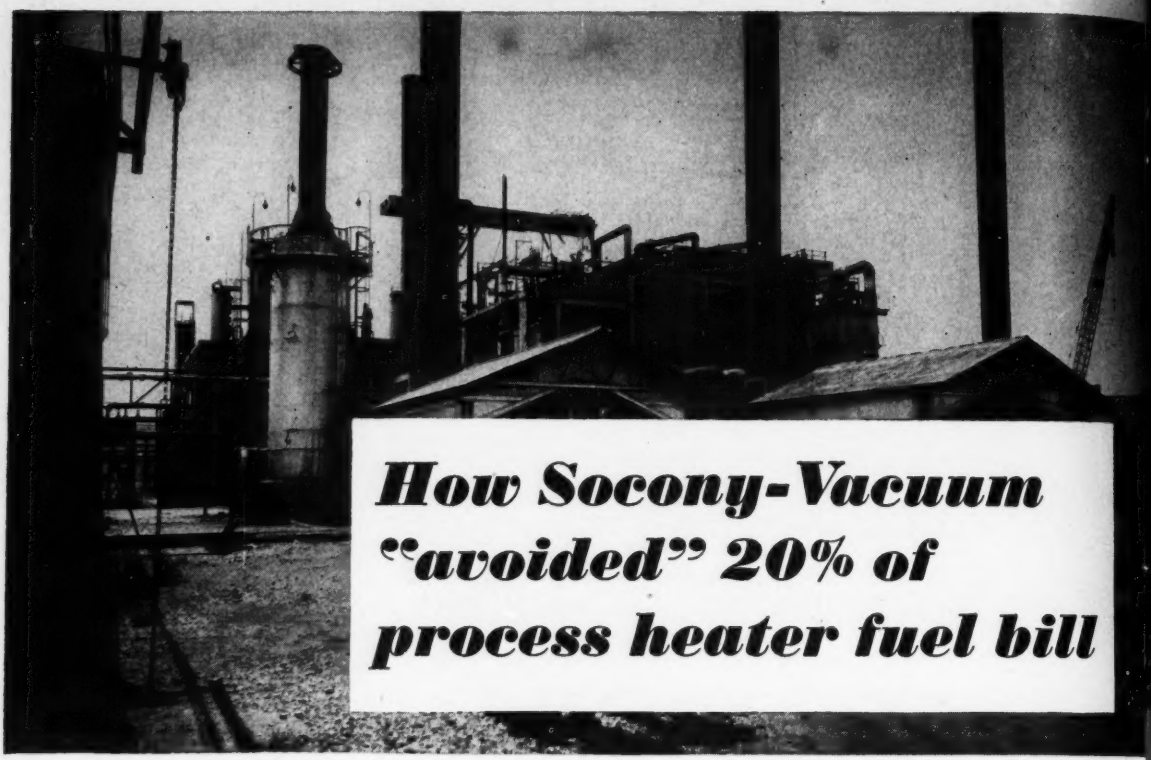
For additional information, write for USG Catalog 64.

United States Gauge, Division of American Machine and Metals, Inc., Sellersville, Pa.

Quality Gauges Engineered for Enduring Accuracy UNITED STATES GAUGE

PRODUCTS OF UNITED STATES GAUGE . . . Absolute Pressure Gauges • Aircraft Instruments • Air Volume Controls • Altitude Gauges • Boiler Gauges Chemical Gauges • Mercury, Gas, and Vapor Dial Thermometers • Glass Tube and Industrial Thermometers • Flow Meters • Inspectors' Test Gauges Precision Laboratory Test Gauges • Marine, Ship and Air-Brake Gauges • Voltmeters • Ammeters • Welding Gauges.

OTHER DIVISIONS OF AMERICAN MACHINE AND METALS, INC. AT SELLERSVILLE, PA.: GOTHAM INSTRUMENTS, AND AUTOBAR SYSTEMS.



How Socony-Vacuum "avoided" 20% of process heater fuel bill

program

When engineers at Socony-Vacuum, Trenton, Michigan refinery developed a complete fuel conservation program, process heaters came under close scrutiny. Socony-Vacuum engineers felt they could reduce the total cost of fuel used in raising the temperature of petroleum stock if they could keep the amount of excess air in the flue gases at a minimum.

need

Socony's instrument engineers wanted an instrument which would indicate excess air, so that they could make adjustments to keep the air at a minimum and thus save fuel.

specifications for instrument

must provide a **continuous indication** so that changes could be spotted immediately.

must **not be affected by changes in fuel composition** since different fuels are used in the heater furnaces.

must not **be affected by the presence of Hydrogen** in the gas sample

preferably, measurement should have **direct relationship to excess air**

selected

four HAYS MAGNO-THERM OXYGEN ANALYZERS and two HAYS 2-PEN ELECTRONIC RECORDERS

results

The entire fuel conservation program brought a 20% reduction in Socony's annual fuel bill. The Hays Oxygen Recorders have proved an effective combustion guide on the process heaters.

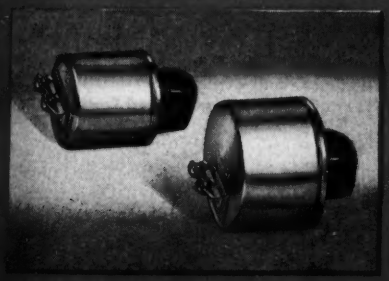
Improvement in the efficiency of your process heaters can mean large fuel savings. Write for Bulletin 50-829, 16 pages of information on how the O_2 meter works, where it's used, etc. No obligation.

THE **HAYS** CORPORATION *MICHIGAN CITY 8, INDIANA*

Ohmite Rheostats, in nine sizes from 25 to 750 watts, meet all requirements of Specification JAN-R-22.

OHMITE RHEOSTATS

MEET REQUIREMENTS OF JOINT ARMY-NAVY SPECIFICATION JAN-R-22



Models H (enclosed) and J (enclosed)
Also AN 3158 (AN-R-14a)

TYPE	OHMITE MODEL	WATT RATING
RP10	H	25
RP11	H enclosed	12.5
RP15	J	50
RP16	J enclosed	25
RP20	G	75
RP25	K	100
RP30	L	150
RP35	P	225
RP40	N	300
RP45	R	500
RP50	T	750

OHMITE RHEOSTATS MEET THESE RIGID TESTS:

★ 5-Hour Vibration Test (Required for RP 10-11-15-16-20-25)
★ 50-Hour Salt-Spray Corrosion Test
★ 150-Hour 95% Humidity Electrolysis Test
and other tests as prescribed in Specification JAN-R-22

By meeting these severe Joint Army-Navy requirements, Ohmite Rheostats have proved what industry has long accepted as true—that they can be depended upon for unfailing performance under the toughest operating conditions. All-ceramic construction . . . a smoothly gliding metal-graphite brush . . . uniform windings locked in place by vitreous enamel . . . insure close control throughout years of trouble-free service. It will pay you to standardize on Ohmite Rheostats for your product.

Be Right with

OHMITE®

RHEOSTATS · RESISTORS · TAP SWITCHES

OHMITE MFG. CO., 4835 Flournoy St., Chicago 44, Ill.

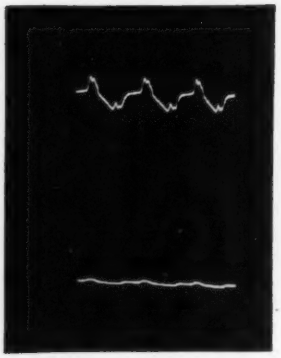
Where "Photographic Memory" Counts!

When you're comparing waveshapes it takes the "photographic memory" of a camera to give you the whole story in accurate, permanent form.

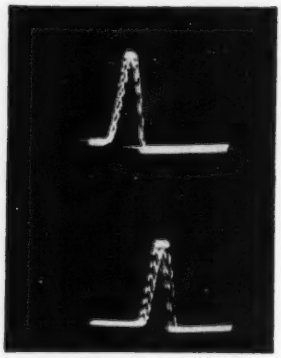
Until recently, photographic oscilloscope recording called for considerable trouble in setting up equipment and a long time period for developing the results. But today, with the Fairchild-Polaroid Oscilloscope Camera, it's an easy job to record as many traces as are needed.

Take a look at the prints below. They provided the engineer with valuable but inexpensive records for immediate evaluation. All were removed from the camera *one minute* after the final exposure was made.

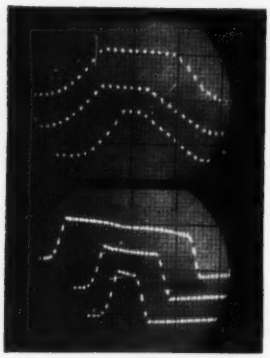
The stories of 3 "One Minute" Oscillograms



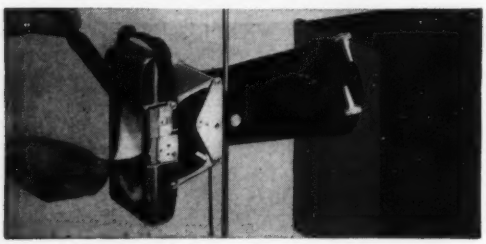
1. BEFORE AND AFTER. A visual comparison of "before and after" conditions is an easy job for the "one step" camera. Here, the upper trace shows the output of a full wave rectified power supply with insufficient filtering. The lower trace shows the effectiveness of the addition of a filtering condenser. The camera is easily adjusted to two positions (upper and lower) for two exposures; traces are exactly one half scope size.



2. SUPERIMPOSING FOR COMPARISON. The problem—determine the maximum time-interval variation between successive camera shutter openings and flash circuit closings. Instead of carefully measuring successive scope traces, the engineer superimposed several exposures for easy comparison. The length of the trace before the shutter opened is a measure of the time between the electrical contact closing and camera shutter opening.



3. MULTIPLE EXPOSURE PRE-SOLARIZATION. Here, by making 3 successive exposures on each half of the print, the engineer was able to record performance of a camera shutter at its 1/100, 1/200, 1/400 second (upper) and 1/25, 1/50, and 1/100 second settings (lower). "Pre-solarizing," the process of pre-exposing the print with the trace off the screen, made it possible to record the high writing speeds involved.



A minute after you've pulled the tab a finished print is ready for evaluation.

for still or *continuous-motion* oscilloscope recording on 35-mm film or paper

—THE FAIRCHILD OSCILLO-RECORD CAMERA

The Fairchild Oscillo-Record Camera is the first unit specifically designed for the purpose of recording cathode-ray tube images. Features: records still or continuous motion on standard 35-mm film or paper, film footage indicator, electronic speed control — 1 to 3600 in./min., film capacity — 100, 400 or 1000 feet.

SPECIFICATIONS

Lens and Shutter—Choice of 75mm f2.8 Wollensak Oscillo-Anastigmat with #2 Alphax shutter having speeds of 1/25 sec. to 1/100 sec., "time" and "bulb"; or, 75mm f1.9 Wollensak Oscillo-Anastigmat with #3 Alphax shutter having speeds of 1 sec. to 1/100 sec., "time" and "bulb".

Picture Size—3¼ x 4¼ in. (2 or more images per print; 16 exposures per roll of film.)

Image Size—One-half reduction of scope image.

Writing Speed—With f2.8 lens, up to 1 in/μsec at only 3000V accelerating potential; higher speeds at higher voltages. With f1.9 lens these values are approximately doubled.

Dimensions—Camera, 10½ x 5¼ x 6¼ in.; hood, 11 in. length, 7½ in. dia; adapter, 2 in. width, 6⅝ in. max. dia.

Weight—Complete, 7¾ lb.

Fairchild-Polaroid Oscilloscope Camera Kits include camera, carrying case and film. Write today for complete data on the Fairchild-Polaroid and Fairchild Oscillo-Record Cameras. *Fairchild Camera and Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N. Y. Dept.* 120-15F.

FAIRCHILD
OSCILLOSCOPE RECORDING CAMERAS

PRESSURE TIGHT WITHOUT LUBRICATION

- **NEW TEFLON-SEAL STUFFING BOX**
- **CUTS METER MAINTENANCE**
- **ELIMINATES LEAKS**
- **ELIMINATES SHAFT FREEZING**

STANDARD IN 1800 PSI ORIFICE METERS

Teflon-Seal Stuffing Boxes have been operating for more than two years without servicing in thousands of orifice meter installations! Applications such as sour gas, wet gas, caustic solutions — almost every conceivable service — have failed to impair meter operation. Maintenance problems are drastically reduced or eliminated!

The Teflon-Seal bearing is pressure-sealing around a precision made, centerless-ground Monel metal shaft, *without grease* and *with minimum friction*. All other stuffing box parts are corrosion resistant stainless steel. The Teflon-Seal Stuffing Box is suitable for ambient meter temperatures to 150°F. and working pressures to 1800 psi. Units are adaptable to older types of orifice meters now in service.

Here is another example of American Meter Company's policy of constant product improvement to uphold a century-old tradition of "*Sustained Accuracy at Lower Cost.*"

See our display, booth 101-5, Sixth National Instrument Exhibit, Sam Houston Coliseum, Houston, Texas, September 10-14.

PROPERTIES OF TEFLON

Teflon (polytetrafluoroethylene) is a synthetic polymer with the following properties: low coefficient of friction — zero water absorption — high impact strength — toughness — form stability — and exceptional chemical inertness. It retains strength at temperatures from —100°F. to 550°F. and does not stick or "weld" to other materials. It resists the attack of all known solvents except molten alkali metals, with no change in weight or properties.

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AMERICAN METER COMPANY

if you need to control

FLOW

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PRESSURE

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of

AIR

GAS

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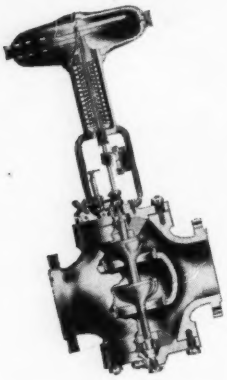

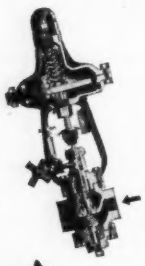

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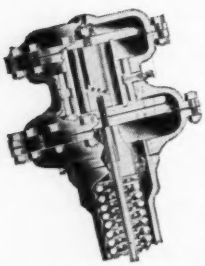

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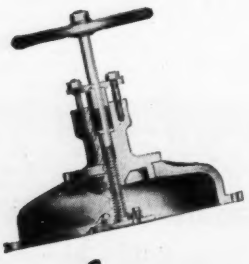


C.

you NEED BS&B "Climax" DIAPHRAGM CONTROL VALVES, Type 86. Here is design and engineering that delivers all the characteristics essential to best process control results. High-lift and characterized inner valves obtain wide rangeability and constant proportional flow increase as valve opens.

Complete versatility is yours. Type 86 Valves are available with reversed topworks (A), duplex diaphragm (B), handwheels (C), finned cooling section, purged gland section, bellows stem packing, steam-jacketed valve bodies and valve positioners. Inner valves are quick-opening, parabolic, V-port, needle and metering pin.

Sizes in double port style ½ inch to 16 inches; single port ½ inch to 4 inches. Pressure ranges are 125 to 5000 psi, within body limits.

Get the complete, detailed story today. Write for new illustrated literature with all the facts on these high-performance Diaphragm Control Valves.

BLACK, SIVALLS & BRYSON, INC.
Adv. Dept., Rm. 51V 7502 East 12th St.
Kansas City 3, Missouri

2

BS&B

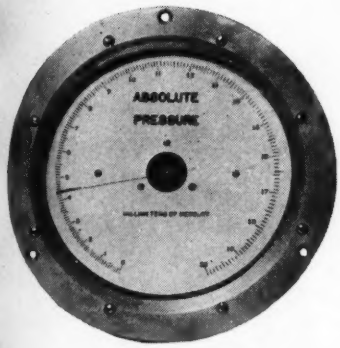
"Climax"
CONTROLS

A-85

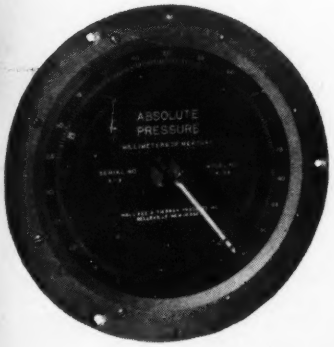
FOR DEEP VACUUM OPERATIONS

W&T PRECISION INSTRUMENTS

FA-193



FA-160 0-20 Scale



0-100 Scale

A-85

THE W&T ABSOLUTE PRESSURE CONTACTOR

This sensitive, yet durable aneroid device is used for actuating an electric circuit at a preset value of absolute pressure.

Outstanding features of the Contactor, type FA-193, include:

Range of adjustment	0-2 mm Hg. and other ranges made to customer's specifications up to 800 mm Hg. absolute pressure.
Sensitivity	will make or break within 0.10 mm Hg.
Contact capacity	5 ma at 115 volts A.C.
Repeatability	0.10 mm Hg.

Vacuum-tight construction
Over pressure protection

THE W&T ABSOLUTE PRESSURE INDICATOR

This precision instrument is used for quick, dependable indications of absolute pressures in the vacuum range. Pressure readings are independent of the nature of the gas. It is available in two dial sizes — 2¾" and 6".

Other features of the Indicator, type FA-160, include:

Range	0-20, 0-50, 0-100, 0-200, 0-410 and 390-800 mm Hg. absolute pressure.
Sensitivity	One part in 500
Accuracy	One part in 300

Over pressure protection
Direct readings
Rugged vacuum-tight construction

THE W&T ABSOLUTE PRESSURE CONTROLLER

The Controller with its associated Electronic Relay furnishes precision control of absolute pressure and provides a continuous indication of absolute pressure. Independent adjustment of the "high" and "low" contacts is made through a magnetic clutch thus eliminating stuffing boxes and seals and ensuring leak-tight operations.

Outstanding features of the Controller include:

Range	0-20, 0-50, 0-100, 0-200, 0-410 and 390-800 mm Hg. absolute pressure.
Sensitivity	One part in 500
Accuracy	One part in 300
Relay contact capacity	5 amps, 110 Volts, 60 cycles non inductive load.

Fast accurate response
Over pressure protection
Vacuum-tight construction

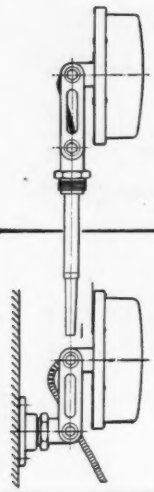
Additional Information Will Be Supplied On Request

WALLACE & TIERNAN
PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities

PALMER

mercury actuated Dial Thermometers

now in three types to suit any requirements

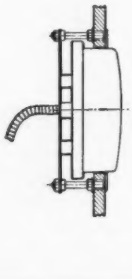


1 Rigid Stem Dial Thermometer

Rigid stem tapered bulb, interchangeable with standard industrial thermometer separable socket.

2 Wall Mounted Dial Thermometer

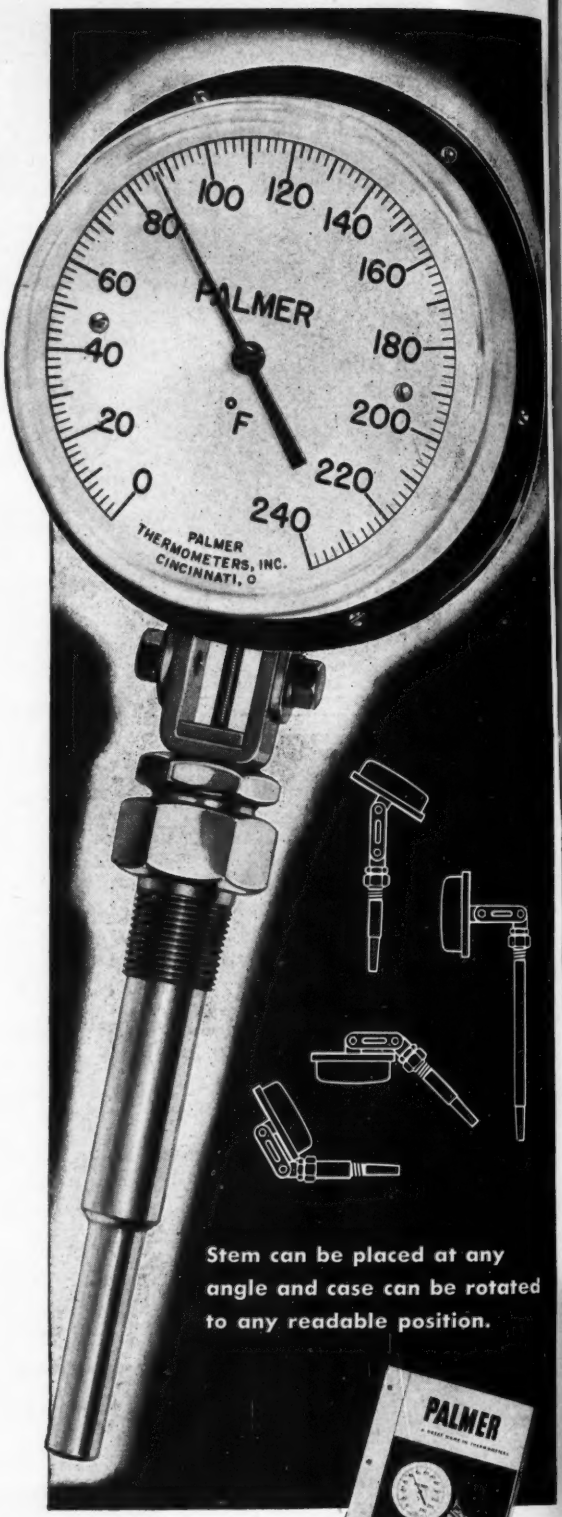
Wall mounted dial thermometer with flexible connecting armor. Case adjustable to easy reading position.



3 Flush Mounted Dial Thermometer

Flush mounted style for panel mounting with flexible connecting armor.

All three types have a full 4½" dial Face



Stem can be placed at any angle and case can be rotated to any readable position.

for accuracy: Mercury actuated . . . Fully Compensated by Invar Compensation. Guaranteed Accurate 1 scale division.

for angularity: Can be adjusted to most readable position at any angle desired.

for readability: Bold Black Numbers . . . 11" of scale Reading Dial face can always be placed in easiest readable position.

for interchangeability: Always specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.

Visit our Booth No. 140-142 at the National Instrument Conference and Exhibit, Houston, Texas, September 10-14, 1951.

SEND FOR THIS BULLETIN

For details on the New Palmer Dial Thermometer, please write for Palmer Bulletin 51-129.

PALMER THERMOMETERS, INC.

Mfrs. of Industrial Laboratory, Recording and Dial Thermometers

2511 NORWOOD AVE., CINCINNATI 12, O.

It's Better than ever!

Improved Design

TYPE 2500-259
with fabricated steel float cage...

and the little Brother and Sister

TYPE 2500-249V
for side vessel mounting

TYPE 2500-249P
for top vessel mounting

Accepted everywhere for

- **LIQUID LEVEL CONTROL**
- **LIQUID LEVEL INDICATION**
- **INTER FACE CONTROL**

Yes — it's preferred, because it gives peak performance. The newly designed Fisher Series 2500 Level-Trol combines many improved features to better meet every field service requirement — to provide longer life with ease of maintenance. Write today for Fisher Bulletin F-3.

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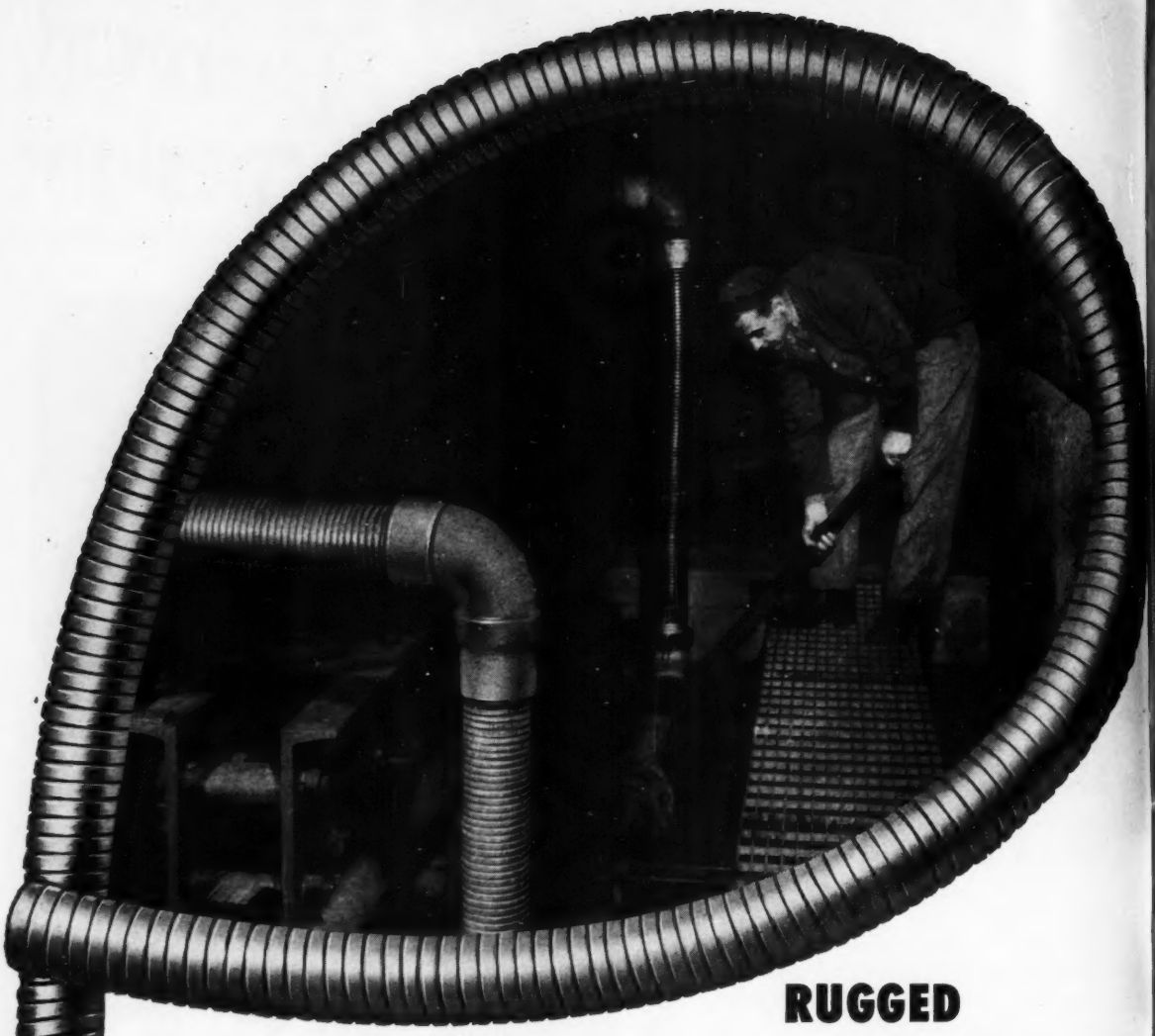
WORLD LEADER IN THE MANUFACTURE OF LIQUID LEVEL CONTROLLERS, PRESSURE REGULATORS AND IN RESEARCH FOR BETTER CONTROL



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Coast to coast . . . border to border, Penflex installations prove the value of "Flexineering"—the science of applying flexible tubing to fit the particular need of the instrument industry. When you require tubing or hose that is as tight as a pipe but flexible, safe at high temperatures . . . free from metal fatigue . . . specify Penflex.

Penflex manufactures a complete line of four wall interlocked and seamless welded corrugated flexible tubing . . . plus automatic barrel fillers, rivet passers, accessories and fittings. Write for the folder that will help your production—"Flexineering."

Pennsylvania Flexible Metallic Tubing Company, Inc., 7212 Powers Lane, Philadelphia 42, Pa.
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PENFLEX
HEART OF INDUSTRY'S LIFE LINES

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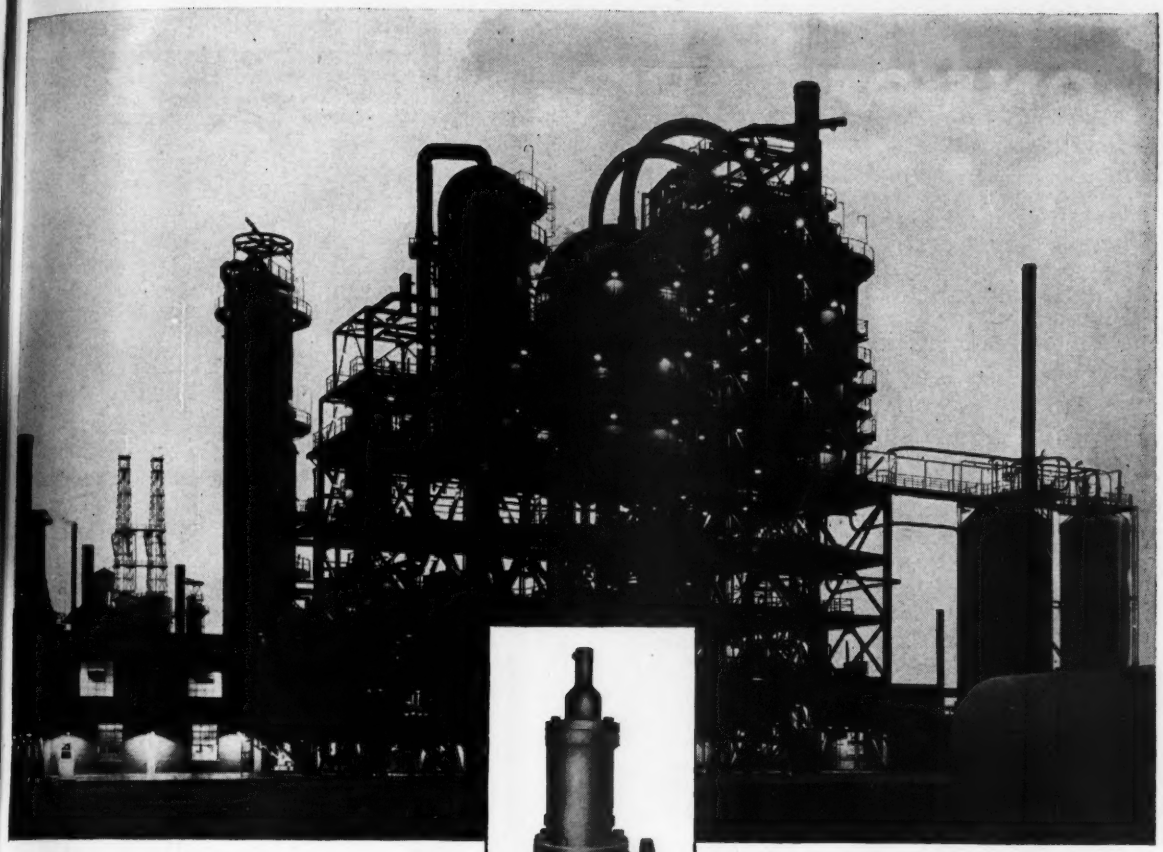
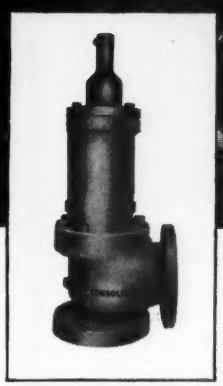




What a Record!

MORE THAN TWO YEARS WITHOUT A "TURNAROUND"!

That's the outstanding initial performance record of this "cat cracker" at the Cities Service Oil Company's refinery, East Chicago, Indiana. Here Consolidated Safety Relief Valves again proved their absolute protection against overpressures in processing equipment.

Leakage under discharge piping stresses is eliminated because of the outside bevel seat and floating guide construction of these valves. The method of establishing the outside bevel seat permits the disc to be moved on a radial seating surface. Complete tightness is assured in all positions within the deflection range, under all conditions of service.

Designed with 25% fewer parts, Consolidated Safety Relief Valves simplify servicing, minimize standardization problems, reduce maintenance costs. Working parts cannot become misaligned — continuous performance is assured at the rated capacity.

Growing defense and civilian needs are crowding refinery capacity. So—depend on Consolidated Safety Relief Valves to help you stretch the time between turnarounds. There's no better valve investment to safeguard life, property and continuous production. Your local distributor will gladly tell you all about these economical, long-life safety relief valves.

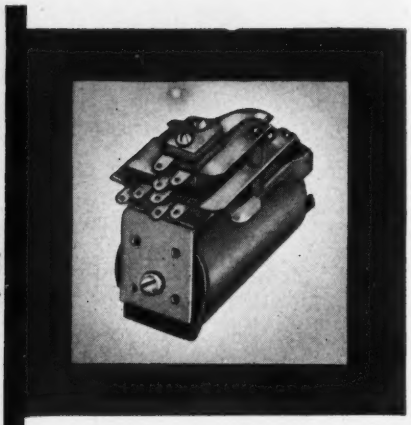
1879 CONSOLIDATED U.S.A.

CONSOLIDATED SAFETY RELIEF VALVES

MAXWELL MANNING MM&M MOORE TRADE MARK

A product of **MANNING, MAXWELL & MOORE, INC.** TULSA, OKLAHOMA

MAKERS OF 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN' ELECTRICAL AND INDUSTRIAL INSTRUMENTS, 'HANCOCK' VALVES, 'ASHCROFT' GAUGES. BUILDERS OF "SHAW-BOX" CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.



GUARDIAN

RELAYS

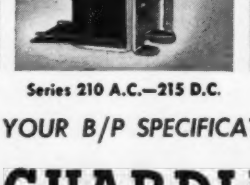
APPROVED BY THE SIGNAL CORPS FOR *Dependable Control*

In peace as in war—men of the Signal Corps recognize the Guardian 695 D. C. Relay as a dependable component of *finest precision* communications equipment. Field telephone sets—walkie talkies—ground to plane—interplane—intraplane—ship to shore radios, all operate perfectly under severest conditions using this tiny relay, either *hermetically sealed* or with open mounting.

Special design of the Guardian 695 D. C. Relay provides an unusually long coil without increasing the overall length of complete unit. Correct balance of copper winding and volume of iron on field piece result in maximum flux density without oversaturation of iron. Up to 6 S.P.S.T. contact combinations. Available with standard open mounting or hermetically sealed *in Lug Header type housing and to specifications in A. N. Connector, Screw Terminal or Octal Plug housings.*

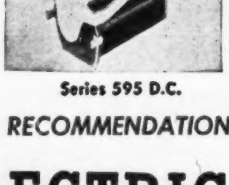
GUARDIAN'S NEW HERMETICALLY SEALED RELAY CATALOG IS YOURS FOR THE ASKING

Series 30 A.C.

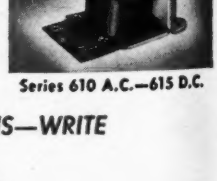


Series 210 A.C.—215 D.C.

Series 220 A.C.



Series 595 D.C.



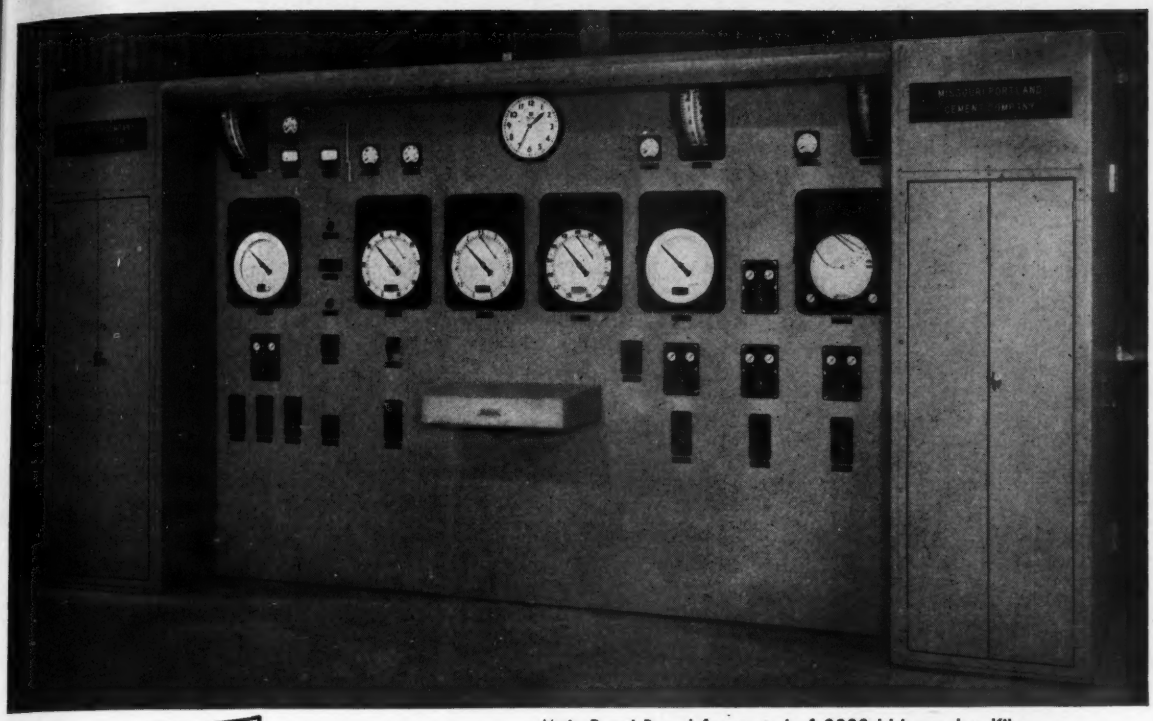
Series 610 A.C.—615 D.C.

SUBMIT YOUR B/P SPECIFICATIONS FOR SPECIAL RECOMMENDATIONS—WRITE

GUARDIAN ELECTRIC

1638-H W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY



Main Panel Board for control of 3000 bbl per day Kiln at Missouri Portland Cement Company, St. Louis, Missouri.

3 Ways Better

...Bailey Control for Rotary Kilns

Bailey Control for Rotary Kilns gives you better performance three ways:

1. Economical Operation
2. Uniform Quality of Product
3. Reduced Maintenance

These are advantages which can be achieved when all phases of kiln operation are coordinated to work together as a team. Here's how Bailey Kiln Control can help you get all three.

ECONOMICAL OPERATION

With Bailey Combustion Control you can be certain that you are getting maximum product for every unit of fuel you burn. Bailey Control closely guards the Fuel-Air Ratio, Hood Draft, Fuel Feed, Clinker Cooling and the Temperature of Air for Combustion.

UNIFORM QUALITY OF PRODUCT

Bailey Instruments and Controls can help you achieve a uniform high grade product. Measurements of temperatures, kiln speed, combustibles content, and oxygen content can be transmitted to recorders on centrally located control boards like the one shown. There is no sacrifice of accuracy or speed of response. High temperature alarm contacts may also be provided with Bailey Pyrometers as a further aid in achieving optimum uniformity of product.

REDUCED MAINTENANCE

By maintaining uniform temperatures and excess air conditions in the kiln, Bailey Controls help to reduce to a minimum costly refractory repairs and wear and tear on auxiliary equipment.

Bailey Meter Company has a staff of engineers who are experts in the control of rotary kilns. Assure yourself of optimum kiln performance. Let one of these men help plan your Kiln Control System. P-22

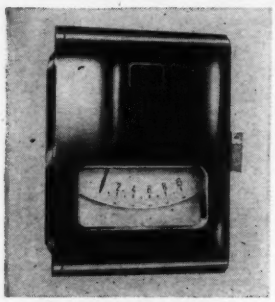
BAILEY METER COMPANY

1041 IVANHOE ROAD • • • CLEVELAND 10, OHIO

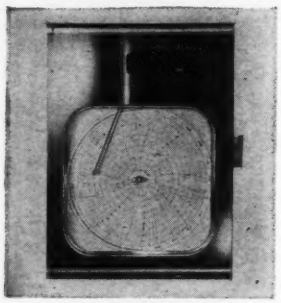
Controls for Processing

TEMPERATURE FLOW
PRESSURE LEVEL
% OXYGEN DENSITY
% COMBUSTION RATIO

HOW TO SIMPLIFY PROBLEMS OF REMOTE MEASUREMENT AND CONTROL



THE TRANSMITTER



THE RECEIVER

Bristol Metameter* Telemetering Instruments Help Step Up Production... Save Time and Money... by Remote Measurement and Control of Pressure, Water Level, Flow, Temperature, Motion, Voltage, Current, Power and Totalized Load.

The Bristol Metameter Telemeter consists of three unit parts: Transmitter, Receiver, and interconnecting line which provides the electrical circuit between the two instruments.

The Transmitter is located close to the point of measurement. Its function is to transmit the readings to the receiver which can be any distance from a few feet to many miles away.

Readings can be transmitted over any two-wire circuit or its equivalent. Private wires, telephone circuits, radio (including microwave), or carrier current channels can be used.

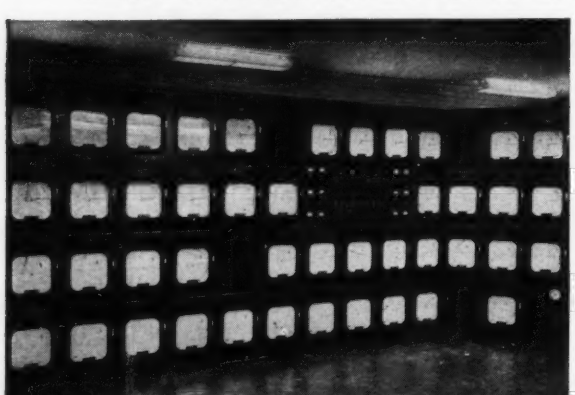
THE TRIED AND PROVED TELEMETERING SYSTEM. Bristol Metameter Telemeter is the product of 37 years of pioneering research and development work. Bristol's continuous program of engineering research and development keeps the Metameter abreast of modern requirements, making it the most reliable and widely used instrument in the field of telemetering.

A few of the thousands of Bristol Metameter Telemeter users:

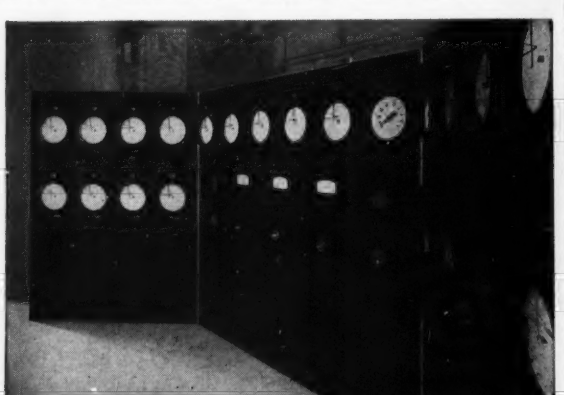
Standard Oil (Indiana), Flintkote, Jones & Laughlin Steel, Bethlehem Steel, Corn Products Refining Company, Champion Paper & Fibre, Mathieson Chemical, New York Central System, McCarthy Chemical, Weirton Steel, Eastman Kodak, United Piece Dye Works, Freeport Sulphur, U. S. Weather Bureau, Bonneville Power Administration, Woodward Iron, Celanese Corporation, Anaconda Copper.

Reg. U.S. Pat. Off.

WRITE US FOR BULLETIN M1700. THE BRISTOL COMPANY, 113 BRISTOL ROAD, WATERBURY 20, CONN.



UNITED STATES STEEL COMPANY These Recording Metameter Receivers provide fuel dispatcher with information concerning gas fuel supply and demand throughout plant at Gary, Ind., help maintain highest production of steel with lowest fuel cost.



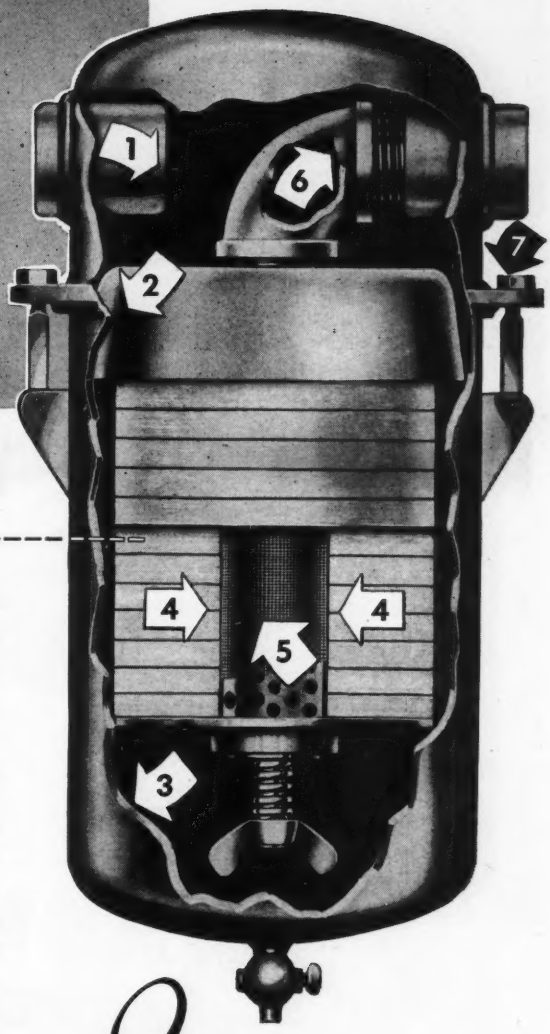
AT THE FORD PLANT Metameter Receivers used by the Ford Motor Company in dispatching gas throughout its Dearborn plant, bring readings of pressure and flow to central point for use of dispatchers. This installation has been in operation since 1936.

THE DEPENDABLE GUIDEPOST OF INDUSTRY

BRISTOL

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Removes Last Traces of Oil and Moisture from *INSTRUMENT AIR LINES....*



THICK FELT DISCS PROVIDE SUPER FILTRATION

DOUBLE ACTION PRINCIPLE REMOVES MOISTURE AND DIRT TWO WAYS—Here's the greatest pipe line filter ever developed for removal of every trace of foreign matter, condensed oil and moisture from instrument control lines. Air is cleaned by both *mechanical separation* and *filtration/absorption.* Air entering filter Inlet (1) strikes Deflector Cup (2) by which heavier droplets of water and dirt particles are directed to sides of Housing (3) and thence downward at high velocity to base where liquid and heavier particles are deposited. The *mechanically cleaned* air then passes at low velocity thru the Discs (4) which *filter* the air and *absorb* the last traces of oil and moisture. Clean, dry air passes out thru fine mesh Bronze Screen (5) and Outlet (6). Swing Bolts (7) on head for easy inspection are optional.

While originally designed for the protection of pneumatically operated control apparatus, these revolutionary filters are now used as a primary or final stage of filtration for an ever-increasing number of tools, devices and processes. Many highly successful installations are reported in which no other filter had proven satisfactory.

Request Bulletin B-1A, mentioning problem involved for specific engineering information. Please direct your inquiry to Dept. 63

Staynew

ABSORPTION FILTER

A complete range of sizes available, handling capacities from 5 to 100 CFM free air at 80 lbs. gauge pressure in standard pipe sizes from ¼" to 2". Model illustrated is AAPHS (swing-bolt head). Available also is Model AAPH, identical except for bolted-head construction.

DOLLINGER REG PROTECTOMOTOR U.S. PAT. OFF STAYNEW FILTERS

DOLLINGER CORPORATION

11 CENTRE PK., ROCHESTER 3, N. Y.

MAGNETRON
PERMANENT MAGNETS AND ASSEMBLIES

with

☆ *Die Cast Aluminum Jackets*
☆ *Sand Cast Aluminum Jackets*
☆ *Celastic Covers*

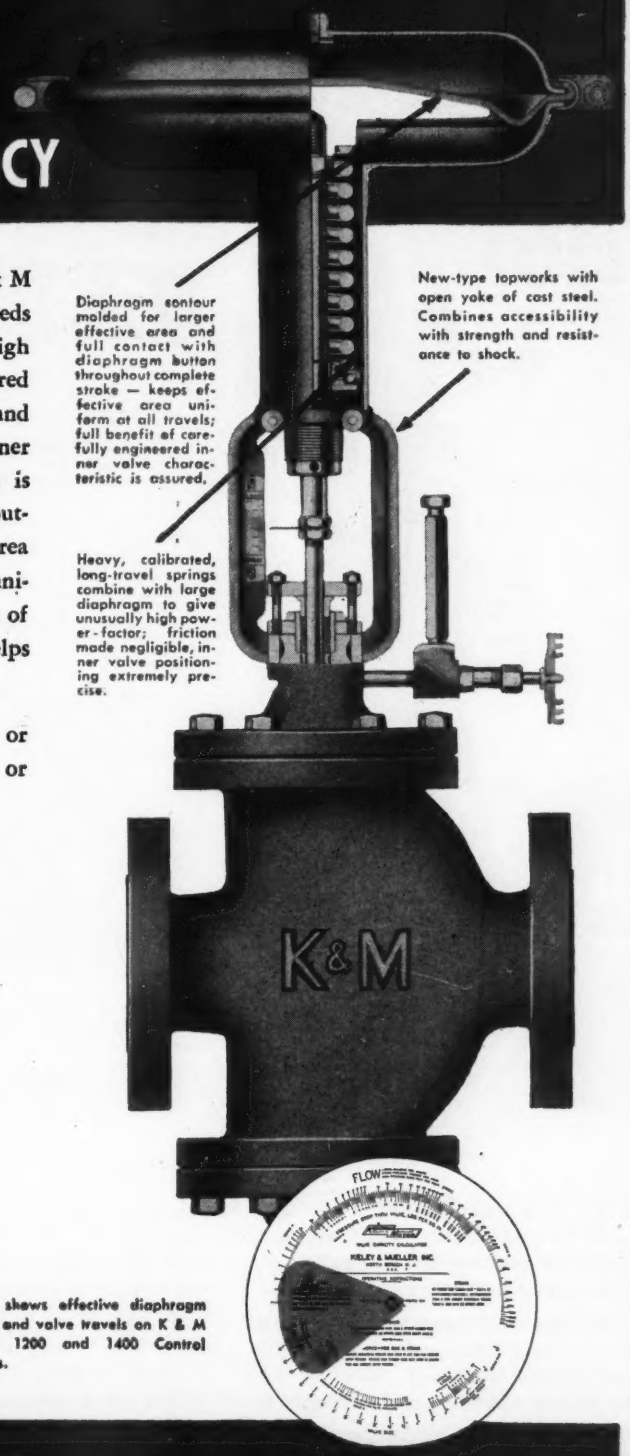
Complete assemblies with Permendur, steel or aluminum bases, inserts and keepers as specified. Magnetized and stabilized as required.

THE ARNOLD ENGINEERING COMPANY
SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION
General Office & Plant: Marengo, Illinois

GREATER POWER for GREATER ACCURACY

The Diaphragm Motor of the far-advanced K & M Control Valve is designed for the more exacting needs of modern process industries. An unusually high power-factor is obtained by the carefully-engineered relationship of large effective diaphragm area and heavy, calibrated spring; friction is negligible, inner valve positioning more precise. The diaphragm is specially designed for constant affinity with the button contour; this assures a uniform effective area throughout the complete valve stroke, thus more uniformly accurate control. The unusually large area of the diaphragm in relation to the valve size also helps assure more precise control.

K & M motors are available for direct action or reverse action without change in effective area or stroke.


Diaphragm contour molded for larger effective area and full contact with diaphragm button throughout complete stroke — keeps effective area uniform at all travels; full benefit of carefully engineered inner valve characteristic is assured.
New-type topworks with open yoke of cast steel. Combines accessibility with strength and resistance to shock.
Heavy, calibrated, long-travel springs combine with large diaphragm to give unusually high power-factor; friction made negligible, inner valve positioning extremely precise.
K&M
FLOW
KIELEY & MUELLER INC.

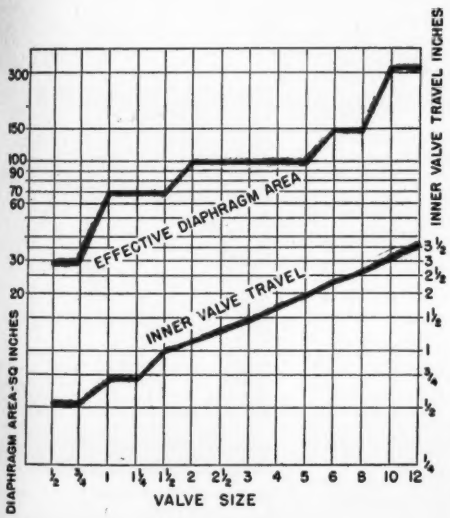


Chart shows effective diaphragm areas and valve travels on K & M Series 1200 and 1400 Control Valves.

KIELEY & MUELLER

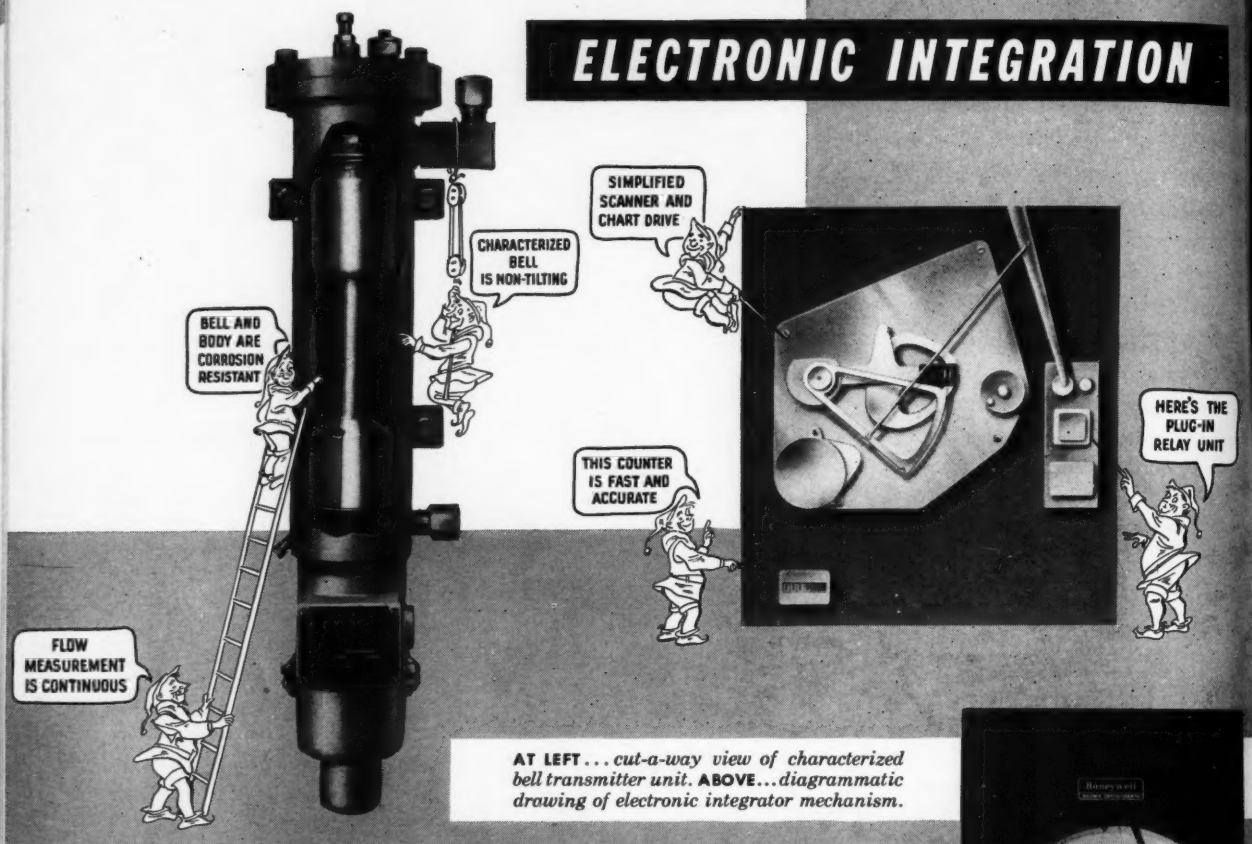
Established 1879

Important Contribution to Flow Measurement and Accounting

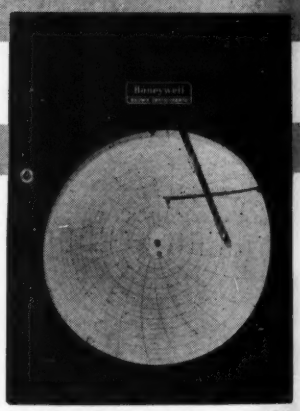
The New

Brown Electric Flow Meter *incorporates . . .*

ELECTRONIC INTEGRATION


SIMPLIFIED SCANNER AND CHART DRIVE
CHARACTERIZED BELL IS NON-TILTING
BELL AND BODY ARE CORROSION RESISTANT
THIS COUNTER IS FAST AND ACCURATE
HERE'S THE PLUG-IN RELAY UNIT
FLOW MEASUREMENT IS CONTINUOUS

AT LEFT . . . *cut-a-way view of characterized bell transmitter unit.* **ABOVE** . . . *diagrammatic drawing of electronic integrator mechanism.*



EVENLY-DIVIDED CHART . . . *provides easy readability for all rates of flow. Write for new Bulletin No. 293-1.*

HERE'S another important advancement for power and process instrumentation...continuous flow measurement, with electronic integration!

This Honeywell development eliminates intermittent measurement and slow, complicated totalizing . . . welcome news to process engineers and accountants.

The electronic integrator, consisting of but three major parts, simplifies accessibility and maintenance . . . permits quick checking and calibration. Scanning is rapid and extremely simple. The corrosion resistant meter body is of tubular construction, reducing weight and bulk. Electrical transmission permits remote, continuous recording of flow...and flow is easily totalized under all conditions. The characterized bell is corrosion resistant, too, and is specially designed to eliminate tilting.

Call in our local engineering representative for a discussion of your application.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division*, 4482 Wayne Ave., Philadelphia 44, Pa.

MINNEAPOLIS **Honeywell**

Brown Instruments

SYLPHON CONTROLS FOR DEPENDABILITY

SYLPHON CONTROLS FOR DEPENDABILITY

NEW!

SYLPHON No. 999 temperature regulator

MORE POWERFUL • STAINLESS STEEL FRAME FOR MINIMUM HEAT CONDUCTION • LESS HEIGHT AND WEIGHT • LARGE SIZE, 2-PLY SYLPHON BELLOWS FOR ADDED POWER • SELF-OPERATING

THIS NEW ADDITION to the Sylphon line is highly recommended for all industrial processes requiring accurate, dependable temperature control. Particularly suited for storage water heaters . . . metal plating tanks . . . bottle washers . . . treaters . . . slashers . . . etc.

Like all Sylphon regulators, No. 999 is self-powered. It requires no compressed air or other auxiliary power source. It's ideal as standard equipment. Thoroughly dependable. Simple and compact. Sturdily built for long service life.

Also available with fin type bulb for controlling temperature of air or gases. Other models: 999-A has over temperature protection; 999-T equipped with dial indicating thermometer. Write for complete details. Ask for Catalog LE-A.

FS

FIRST WITH BELLOWS

Temperature Controls • Bellows Devices • Bellows Assemblies

FULTON SYLPHON
DIVISION

ROBERTSHAW-FULTON CONTROLS CO., KNOXVILLE 4, TENN.

Canadian Representatives, Darling Brothers, Montreal

Few meters have

ANY *of these features—*

only HAGAN

RING BALANCE

has **ALL**

1. No stuffing boxes.
2. Mercury level not critical.
3. Dead-weight calibration.
4. Adjustable over a 7 to 1 range of differentials.

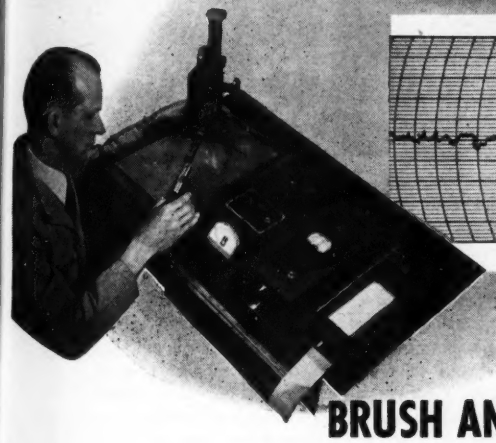
For full information on these meters, or on any application in which you are interested, write to Hagan Corporation, Hagan Building, Pittsburgh 30, Pa.

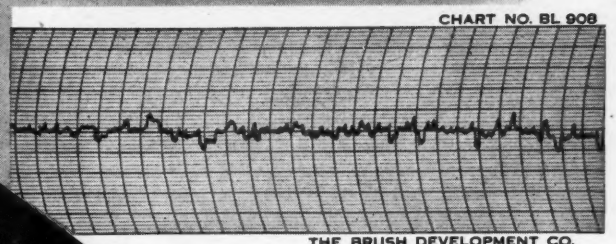
HAGAN HALL BUROMIN CALGON

HAGAN CORPORATION

RING BALANCE FLOW AND PRESSURE INSTRUMENTS
THRUSTORQ FORCE MEASURING DEVICES
BOILER COMBUSTION CONTROL SYSTEMS
METALLURGICAL FURNACE CONTROL SYSTEMS

How good is the surface?





Profile chart of test surface gives positive, numerical answer to smoothness questions. Distance between each horizontal line on chart represents one micro-inch.

BRUSH ANALYZER GIVES YOU COMPLETE DATA

... in writing

• With the Brush Surface Analyzer* you can obtain not only numerical evaluation of surface smoothness, but also a highly magnified profile of the surface in chart form—enlarged beyond the range of optical microscopes. Variations of less than 1/1,000,000 of an inch are readily apparent, and can be measured on the calibrated chart.

To check any surface—metal, glass, plastic, paper, etc.—the Analyzer probes the surface with a Brush crystal pickup. A "hill and dale" chart is drawn by the recorder, and the average finish is also indicated on a large illuminated scale.

The Brush Surface Analyzer eliminates guesswork in specifying and checking finishes. Exact numerical values can be specified and verified. Where desired, customers can be provided with a permanent record of inspection results.

If you manufacture or use precision parts, find out how you can benefit from the accurate measurements made possible by Brush Surface Analyzers. And investigate other Brush Analyzers for studies of a-c or d-c voltages or currents, strains, displacements, light intensities, temperatures, and other static or dynamic conditions.

Write for information. The Brush Development Company, Department A-10, 3405 Perkins Avenue, Cleveland 14, Ohio, U. S. A. *Canadian Representatives:* A. C. Wickman (Canada) Ltd., P. O. Box 9, Station N, Toronto 14, Ontario.

*Trade Mark Registered in U. S. Pat. Off.

Put it in writing with a

BRUSH RECORDING ANALYZER

THE *Brush* DEVELOPMENT COMPANY

PIEZOELECTRIC CRYSTALS AND CERAMICS • MAGNETIC RECORDING
ELECTROACOUSTICS • ULTRASONICS • INDUSTRIAL & RESEARCH INSTRUMENTS

ENJOY MULTIPLE SAVINGS

IN TIME, SPACE and MONEY

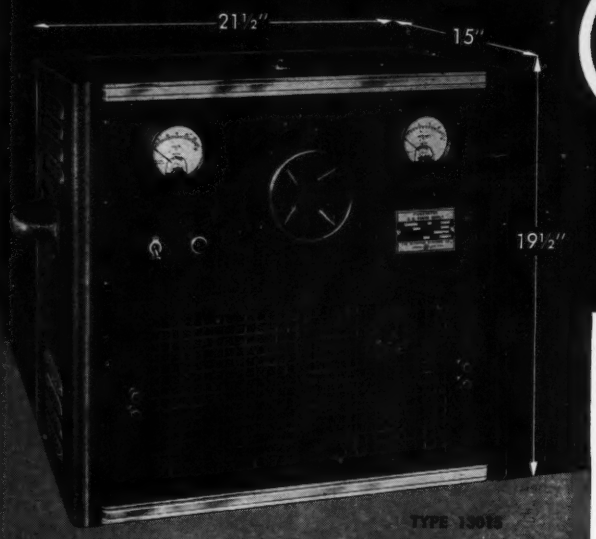
WITH A

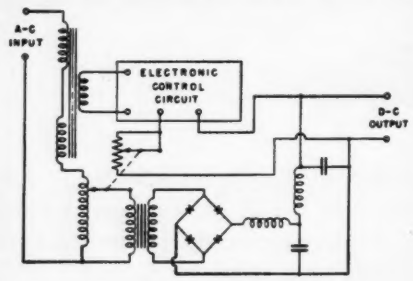
SECO Varicell

STABILIZED – REGULATED

VARIABLE D-C VOLTAGE

FROM AN A-C SOURCE





In keeping with rapid advancements of the electronic and nuclear fields, The Superior Electric Co. has developed the VARICELL D-C power supply. It provides a multiple range of regulated and stabilized low D-C voltages operating from an A-C source. You buy one compact unit — no need for several purchases, no need for accessories or special parts — to handle 6, 12 and 28 volts output. Control is centralized, space is conserved and engineers, technicians and test men welcome the convenient dependable performance.

VARICELL type 13015, illustrated above, is rated 95-135 volts, 60 cycles, 1 phase, A-C input; and 0-30 volts, 15 amperes D-C output. Stabilization and regulation is ±0.25 volts and R.M.S. ripple voltage never exceeds 0.1 volt for the output range of 6 to 30 volts. Any output voltage setting is not affected by line voltage changes or load current variations. For more detailed information fill in handy coupon and mail.

WRITE FOR VARICELL BULLETIN TODAY

THE SUPERIOR ELECTRIC CO.
BRISTOL, CONNECTICUT

THE SUPERIOR ELECTRIC CO.
707 Church Street, Bristol, Connecticut

Please send me more information on_____
Please have a SECO Voltage Control Engineer call ☐

Name_____

Company_____

Co. Address_____

City_____ Zone___ State_____

MANUFACTURERS OF VOLTAGE CONTROL EQUIPMENT

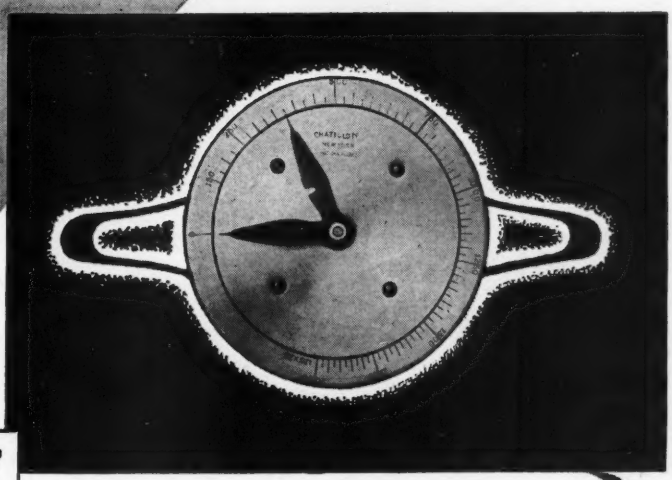
- POWERSTAT VARIABLE TRANSFORMERS
- STABILINE VOLTAGE REGULATORS
- VOLTBOX A-C POWER SUPPLIES
- VARICELL D-C POWER SUPPLIES
- 5-WAY BINDING POSTS
- LIGHT DIMMING EQUIPMENT

WHEN THE PRESSURE OF INDUSTRY IS GREAT...COUNT ON CHATILLON FOR UNFAILING AID!

Since 1835, John Chatillon & Sons have been world famous for the precision manufacture of force measuring devices which meet the most specific requirements of industry.

CHATILLON TRACTION DYNAMOMETERS

- For determining sag in stringing transmission lines.
- To ascertain force required to pull underground cables and wires through conduits.
- For guy wire tensions, pole, insulator and anchor strength.
- For use in conjunction with apparatus that apply force to test strength of materials and structures.
- Gear Mechanism is Enclosed in Dustproof housing.
- Accuracy is Guaranteed to within 2% plus or minus of dial reading.



Traction Dynamometers are made in Capacities shown below:

Capacity & Graduations in lbs.	First Dial Reading lbs.	Dial Dia. Inches	Shipping Weight lbs
1000 x 10	100	7	8
2000 x 25	150	7	9
5000 x 50	250	8	9
10000 x 100	500	10	15
25000 x 200	600	14	45
50000 x 250	1000	16	56
100000 x 500	1000	18	95

Larger Capacities to Order

FILL IN AND MAIL COUPON TODAY

John Chatillon & Sons, 87 Cliff Street, New York 7, N. Y.

Gentlemen: Please send me complete brochures on

☐ Traction Dynamometers ☐ Push Pull Gauges
☐ Laboratory Scales ☐ Force Measuring Devices

Name.....Company.....

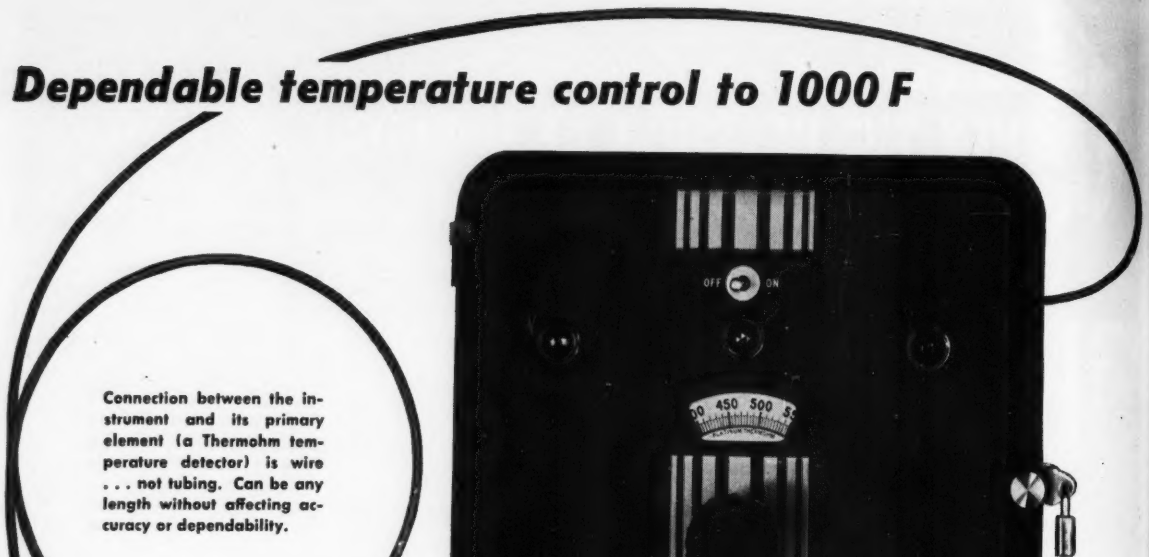
Address.....Position Held.....

JOHN CHATILLON & SONS

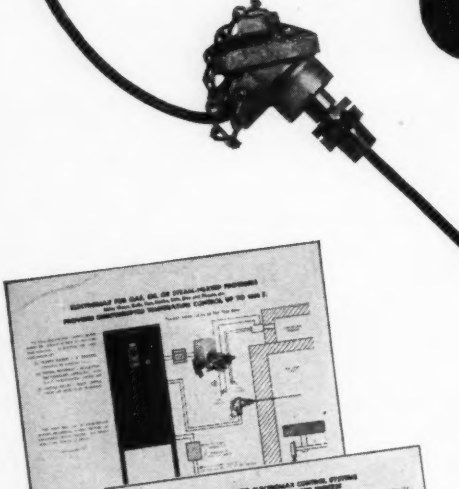
87 CLIFF STREET, DEPT. 16, NEW YORK 7, N. Y.

Manufacturers of Precision Instruments Since 1835

Dependable temperature control to 1000 F



Connection between the instrument and its primary element (a Thermohm temperature detector) is wire . . . not tubing. Can be any length without affecting accuracy or dependability.



Typical samples of the information available on Electromax Control. Specify nature of process and whether fuel is gas, oil, steam or electricity.

ELECTROMAX Controllers give modern electronic regulation to thousands of important manufacturing processes. In any application up to 1000 F they exactly fill the bill for non-recording controllers of outstanding dependability.

Electromax has the sensitivity, accuracy and dependability of its big brother Speedomax Recording Controller. Likewise, it is not affected by vibration or building tremors . . . can even be mounted on the frame of a molding press. The instrument needs almost no attention, because it has only one moving part . . . a covered plug-in type relay. There's usually no need to open the instrument door for months at a time.

Electromax Control is available to provide any one of three control actions. For the more simple process requirements, on-off or two position control is usually used. For processes requiring control within unusually close limits, two different types of proportional control are available . . . Position-Adjusting Type and Duration-Adjusting Type. All three types of control action can be applied to electric, steam or fuel heating.

For further information, write our nearest office, or 4955 Stenton Ave., Phila. 44, Penna.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl Ad ND47(2)

Instruments THE MAGAZINE OF Measurement and Control

M. F. BEHAR, Editor

Plan Your Trip to Houston Now

EVERY reader of these lines who can possibly go to Houston in early September should plan to do so. According to an ISA press release, Houston will then be the scene of the largest instrument exhibit "ever held in the Western Hemisphere."

And that's no Texas press-agent exaggeration! The number of companies that have signed up for booths at this writing is 147—the largest yet; the total number of booth spaces—219—is likewise the largest; and the 25,000 square feet of actual exhibit space likewise sets a new record.

As usual (for the sixth consecutive year) the August issue of *Instruments* will feature the floor plan, the exhibitors' directory and the programs of the ISA and of the eight cooperating societies and institutions. These are:

Instruments and Regulators Division of the American Society of Mechanical Engineers; Instruments and Measurements Committee of the American Institute of Electrical Engineers; Institute of Radio Engineers; American Institute of Physics; Gulf Coast Spectrographic Society; National Association of Corrosion Engineers; Texas Agricultural and Mechanical College; The Piper Liner's Club.

With so many cooperating organizations, the total number of technical sessions will probably set a new record. During the hours devoted to presentation of technical papers, THREE sessions will be going on simultaneously—but almost always on different subjects. Then, too, there will be numerous society and institution luncheons and dinners—with invited speakers who are prominent in their respective fields.

In addition to this imposing technical and social program, the Houston Conference will also be the scene of the Third Pre-Conference Instrument Mechanics' Maintenance Clinic. This is a once-a-year opportunity for 200 instrument mechanics to get twenty hours of instruction on installation, trouble-shooting, maintenance and repair of the instruments of ten of the companies who participate in the Exhibit. The Clinic students, in small groups, attend classes on the Friday, Saturday and Sunday immediately preceding the opening of the Exhibit. Instructors and demonstration equipment are supplied by the instrument companies. At the conclusion of the Clinic, students—who receive a certificate—are free to attend the Exhibit or the Conference sessions beginning on Monday morning.

Companies participating in the Houston Clinic are: Brown Instruments Division of Minneapolis-Honeywell Regulator Co.; Fisher Governor Co.; Foxboro Co.; Hagan Corp.; Leeds & Northrup Co.; Manning, Maxwell & Moore, Inc.; Mason-Neilan Regulator Co.; Moore Products Co.; Republic Flow Meters Co.; and Taylor Instrument Companies.

The Clinic will be held in the E. W. Cullen Building on the campus of the University of Houston on September 7th, 8th and 9th. The Conference will open Monday, September 10th, and will continue through Friday. Technical sessions will be held at the Sam Houston Music Hall throughout the week. The Exhibit will be held in the Sam Houston Coliseum; it will open Monday at 12 noon. It may be attended without charge upon proper registration. A small fee will be charged for attendance at the technical sessions.

Crucial Need of Automatized Inspection

IT was on doctor's order that your editor spent a month in Southern California. Although anything resembling work had been forbidden, invitations to visit plants and labs proved irresistible—but now, on looking back, there's no cause for regret. On the contrary: only by observing with one's own eyes could one grasp the tremendous progress that has been made in missile guidance—to name only one field of modern instrumentation for which Southern California would be famous IF details could be published. Only by conferring with leaders of Research and Development teams and with Production Managers could one appreciate the seriousness of the problems that remain to be solved in order that our beloved nation can win the new races for supremacy. Our only regret is that we didn't disobey the doctor until after two full weeks of idling in the sun. But we saw and heard enough in the last two weeks to make us want to urge and implore every reader to do his utmost to automatize America's Defense Effort.

America's ace-in-the-hole is Instrumentation; but we Americans are not sufficiently accelerating and expanding the use of measurement-and-control techniques. Wonders are being accomplished in developing new weapons utilizing Instrumentation principles; also in developing new instruments for detection, interception, etc., but the rate of production of most new Defense items is inexcusably slow. One reason: the production rate of NEW COMPONENTS is inexcusably slow. This is true not only in California but wherever sub-contracts have been awarded.

For America to survive, her output per man-hour must rise by 2 to 4 percent EVERY year—as it rose in the past. Since returning from California, we've tried to ascertain the man-hour outputs in Pittsburgh, Cleveland, Detroit, and other districts; and if our informants are correct, Industrial America is slipping, slipping, slipping!

The most urgent need is to automatize the production and inspection of the new components—especially their inspection. All over the country there is such a shortage of human inspectors that standards risk being lowered—thereby lowering production by increasing rejection wastage and impairing interchangeability.

No men are better qualified to remedy this deplorable situation than are *Instruments*' subscribers. One group in Pittsburgh has organized an Inspection and Gaging Committee within the ISA. Similar groups should organize elsewhere—formally or informally—without delay.

The production and inspection of mechanical components became almost a "manless factory" miracle in the course of the second world war; now let the production and inspection of the new components be automatized!—MFB

"2 for 1"

Can you spare your January 1951 Issue of *Instruments*?

Our stock is exhausted. We need copies for emergencies. If you send us your copy, we'll extend your subscription *two months*. (Notes—1. Write your name and address on the *envelope*. 2. Copy must be unmutilated.)

"2 for 1"

INSTRUMENT ELECTRONICS

By M. H. ARONSON, Managing Editor, Instruments

I. THE ELECTRICAL NATURE OF MATTER

ABSTRACT.—A brief history is given of the methods by which the atom and its constituent parts, particularly the electron, were discovered and measured. Current, direction of current, current sources, and current values are explained.

ELECTRONICS deals with the actions of electrons in gases. Although the principal electronic devices are vacuum tubes and gas tubes, the tubes are always a part of electric circuits which include resistors, capacitors, various sources of potential, etc. The application of electronics in industry is so extensive that every technical worker in the field of industrial instrumentation should be familiar with the principles of operation of electronic devices and electric circuits.

Although most books about the history of physics begin with the writings of the Greeks Pythagoras (about 500 B. C.), Aristotle (about 350 B. C.), Euclid (about 300 B. C.), and Archimedes (about 250 B. C.), it was only in the nineteenth and twentieth century that experimental evidence was used to prove conclusively that (1) matter is made of atoms and molecules, (2) there are only about 100 different types of atoms, called elements, and (3) atoms are made of particles, the most important of which are electrons, protons, and neutrons.

A brief review of some of the early experiments which were used to establish these well-known facts helps to remove the aura of mystery and wonder that surrounds the unimaginably small dimensions and wondrously large numbers associated with the electrical components of matter.

EDITOR'S PREFACE

JUDGING from impressions on browsing in a technical library, the number of books and articles on the subject of electronics appears to be almost as great as the number of people working in the field and interested in the subject.

This new series on Instrument Electronics, however, differs in the important respect that it is based on a home-study correspondence-course approach. Here is the opportunity either to teach yourself or to check yourself on electronic principles and instrument applications.

Mr. Aronson is well fitted for the difficult job both of writing and teaching the subject of instrument electronics. Since graduating from the Physics Department of Carnegie Institute of Technology in 1939, his experience has included work as instrument engineer, electronics research and development man, head of the Electronics Section of the Naval Training Publications Center, and now Managing Editor of *Instruments*. His books and home-study courses on electronics are being used by the Navy in the training of electronics personnel.

This series starts with electrical fundamentals, so that anyone interested in the subject can read, study, and learn. The emphasis will be on instrumentation applications—waveshaping, limiting, counting, integrating, differentiating, d-c. amplification, etc. All categories of electronic instruments will be surveyed and described.

Best of all: each article is followed by a multiple-choice quiz.

M. F. BEHAR
Editor, *Instruments*

MASS OF THE ATOM

In 1828 Robert Brown discovered a continuous irregular motion of very small particles suspended in a fluid. It was proved that moving molecules of the liquid caused this motion by bombarding the particles in the liquid, and that all molecules in matter move at a rate dependent on the temperature of the matter. Careful analysis of this thermal, or Brownian, motion yielded values for the kinetic energy of the motion.

A German physicist, Otto Stern, made direct measurements of the velocities of sodium atoms in a vacuum. Once the kinetic energy (K.E.) and velocity (v) of sodium atoms were known, the mass was calculated from the formula for kinetic energy:

$$K.E. = \tfrac{1}{2}mv^2.$$

As the relative weights of all the elements were known, the masses of all the elements were calculated. The mass of the lightest atom, hydrogen, was found to be 1.6×10^{-24} gram.

VOLUME OF THE ATOM

An important discovery that had been made earlier by chemists was used to determine the size of the atom. This discovery was that if we take a quantity of matter whose weight in grams equals its molecular-weight—that is, a *mol*, or gram-molecule—there is a fixed number of molecules in that amount of matter. This number, called Avogadro's number, is about 6.0×10^{23}. As the molecular weight of water is 18, there are 6.0×10^{23} molecules in 18 grams of water, or about 3.3×10^{22} molecules in 1 gram of water. But 1 gram of water occupies 1 cubic centimeter of volume. Therefore, the volume of 1 molecule of water must be $1/(3.3 \times 10^{22})$ cubic centimeter. It is interesting to note that the number of molecules of water in a drop of water is about the same as the number of drops of water in Lake Michigan.

Once the masses and diameters of atoms and molecules were known, the internal structure of the atom was investigated. As different atoms possess different properties, the logical theory that these differences were due to variations in the internal structure of the atoms was advanced in a later part of the nineteenth century. One of the earliest observations made was that electric charges of two kinds were produced by rubbing certain materials together. Therefore, it was theorized that atoms contain two kinds of electric charge, which were called positive and negative. The negative charges were called *electrons* by Dr. G. J. Stoney in 1891.

THE ELECTRON

About this time it was discovered that a discrete particle of electric charge exists. Electrically charged atoms, or ions, were used to experiment with this idea. The way to produce ions is to add an electrical charge to, or subtract it from, a normally neutral atom. The process is called ionization.

One simple way to produce ions is to dissolve a salt such as silver nitrate in a solvent such as water. The neutral molecules of the silver-nitrate salt break up into positive silver ions and negative nitrate ions. The solution is known as an electrolytic solution. Electroplating is accomplished by inserting positive and negative electrodes into the electrolytic solution. The positive ions are attracted to and deposit themselves on the negative electrode, and the negative ions migrate to the positive electrode.

Michael Faraday, an English scientist of the early part of the nineteenth century, found that a relation existed be-

tween the amount of electricity passed through an electrolytic solution and the amount of material deposited on the electrodes. Faraday showed from this that the electric charge carried by atoms is always a whole-number multiple of a certain elementary amount of charge. This unit of charge is now known to be the charge on one electron. The charge on the electron is the smallest unit of charge.

Robert Millikan, an American scientist, performed a fundamental and far-reaching experiment in 1909. By observing the motion of minute drops of oil in an electric field (Fig. 1), he found that the electric charge developed on the oil droplet when it was irradiated with ultraviolet light was always a whole-number multiple of a small unit of charge. This minimum amount of electric charge turned out to be exactly the same as the smallest unit estimated from the afore-mentioned electrolyic experiments by Faraday. This and other evidence proved conclusively that there exists a unit electrical charge, the charge on an electron.

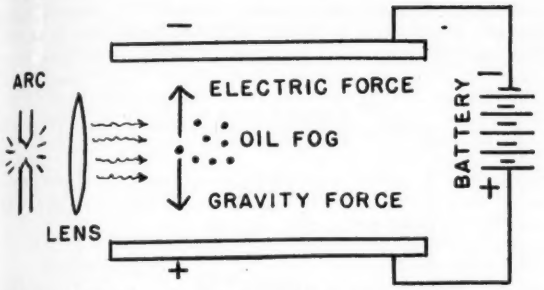


Fig. 1-1. Millikan's apparatus for measuring the elementary electric charge.

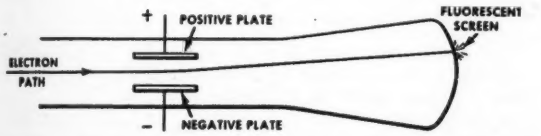


Fig. 1-2. Thompson's arrangement for measuring the ratio of the charge to the mass of an electron.

Thus far we have mentioned the discovery of a unit of matter, the atom, and a unit of charge, the charge on an electron. After the atom and electron were discovered efforts were made to obtain and measure a "separate" electron.

Photoelectricity

All bodies become electrically charged positive when illuminated with ultraviolet light such as that produced by an electric arc. Millikan used ultraviolet light to develop charges on the oil droplets in his experiment for measuring the charge on an electron. As ultraviolet light does not carry any electric charge, it cannot supply the positive charge to the body it illuminates. We must conclude, therefore, that the observed effect is due to the loss of negative charges, or electrons, by the illuminated surface. Some substances are so sensitive that they emit electrons when illuminated with ordinary light. This phenomenon, known as photoelectricity, was one of the methods used to obtain a free electron in space.

Thermionic Emission

A similar effect was noted in hot bodies. Experiments proved that negative charges are emitted from the surface of hot bodies, particularly from metals. This phenomenon, called thermionic emission, is another method by which free electrons may be obtained.

As all matter consists of atoms, it was theorized that the effect of heating and illuminating a body is to extract negative charges from the atoms. The particles of negative charge, therefore, must be loosely bound constituent parts of atoms because they escape easily from the atom.

Mass of the Electron

The question of whether electrons possess any mass was investigated next. The ratio of the electric charge of an electron to its mass was first measured at the end of the last century by the British physicist, Sir J. J. Thomson. Thomson permitted a beam of electrons, obtained by either photoelectric or thermionic emission, to pass between the charged plates of a capacitor (Fig. 2). The electrons, being negatively charged, were attracted by the positive plate and repelled by the negative plate. The deflection was observed by permitting the electron beam to fall on a fluorescent screen. This was the forerunner of the modern oscilloscope. The deflecting force acting on the electrons as they passed through the capacitor was directly proportional to the charge on the electron, but inversely proportional to the mass of the electron. Thus the ratio of charge to mass, or specific charge, was derived from the experiment.

As the charge of the electron was known from the experiments of Millikan and Faraday, the mass of the electron could now be calculated. It was found that the mass of the electron is 1/1,840 that of the lightest atom, the hydrogen atom. The electron is the lightest known mass. The high speed of response of electronic circuits is due to the exceedingly small mass of the electron. As it is practically weightless, it can be accelerated to high speeds and then stopped instantaneously.

Internal Structure of the Atom

After the atom and electron were discovered, the problem of what the atom consists of was attacked by many scientists. As the atom apparently contains negative electrons, and as it is normally uncharged, it must contain a number of positive charges equal to the negative charges. Early workers thought that the atom was like a bean bag filled with equal numbers of positive and negative "beans" homogeneously distributed throughout the bag. But experiments carried on by Lord Rutherford and others showed that this could not be a true picture of the atomic model.

Let us consider what would happen if somebody shot at a bean bag with a high-speed gun. We would expect the bullets to be slowed down and to be slightly deflected from their course by collisions with the beans in the bag. Rutherford shot high-speed alpha particles, which are emitted by radioactive substances, at atoms.

He found that most of his "bullets" were not deflected, that many were only slightly deflected, that a few were deflected greatly, and that occasionally a few deflected backward. The only way that Rutherford could explain his results was by assuming that the atom, instead of being a homogeneous mass, was really composed of a small, very dense nucleus, plus a shell of lighter particles. As most of his projectiles had not been deflected, Rutherford reasoned that most of the volume of the atom is empty space.

Several years later Niels Bohr, a Danish physicist, presented a theory of the atom, for which he was awarded the Nobel prize for physics in 1912. According to Bohr's theory, the atom is like a solar system. At the center is a dense nucleus corresponding to a sun. At a relatively great distance away from the center are many lighter particles, which spin around it in circular or elliptical orbits. Just as most of the volume of a solar system is empty space, the atom also is mostly empty space. Bohr said that the central mass is composed of the positively charged particles, called *protons*. The particles moving in orbits around the nucleus are the lighter, negatively charged *electrons*.

The chemical properties of elements are completely determined by the number of protons and electrons contained in the atoms of the elements. The diagrams of a few of the simpler atoms are given in Fig. 3. Note the relatively small volume occupied by the nucleus and the large volume of free space. Note also the small mass of the electron as compared with that of the proton. As the proton is about 1840 times as heavy as the electron, the mass of the atom is determined mostly by the number of protons in the nucleus of the atom.

The lightest and simplest atom is the hydrogen atom. The

hydrogen atom has a single proton in the nucleus and a single electron. As the hydrogen nucleus is a single proton, the symbol for the proton is H^+. The symbol for the electron is e^-, or simply e. As hydrogen is the lightest element, an atom of hydrogen is said to have a mass of one. The next heavier atom, that of helium (He), has a mass of four relative to hydrogen and therefore was expected to contain four protons. However, it was found that the helium atom has only two protons instead of the four expected because of its weight. The rest of its mass was found to come from two additional particles called neutrons, also located in the nucleus of the atom. The neutron has the same mass as the proton but no charge. The symbol for the neutron is the letter n.

In addition to the electron (e^-), neutron (n), and proton (H^+), there was discovered another constituent particle

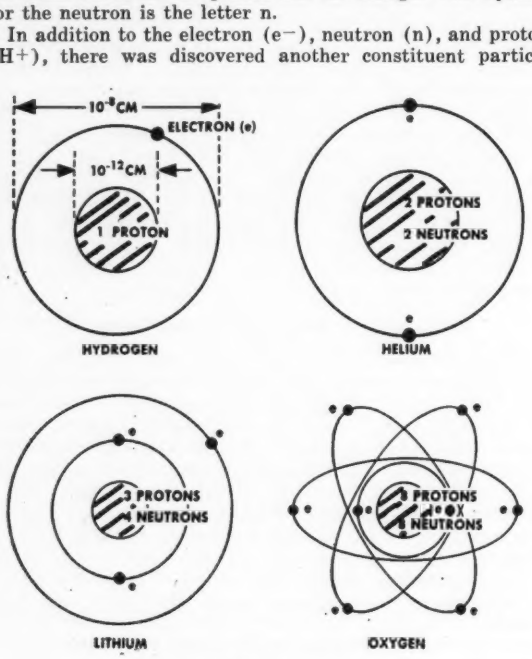


Fig. 1-3. Models of simple atoms.

of the atom, the positron. The positron is a particle that has the same mass as the electron, but, whereas the electron has unit negative charge, the positron has unit positive charge. The symbol for the positron is e^+. The positron is a recent discovery. It is formed only when high-energy radiation strikes a nucleus, and it has a short life. Therefore, it is not found in electronic circuits as are electrons.

Although physicists have discovered and named *fifteen* different kinds of subatomic particles, the electron, proton, and neutron are most important in the performance of electronic devices. Charged atoms and molecules (i.e., ions) also are important in instrument electronics.

Current

A current is simply a flow of electric charges. The charges can be either positive or negative. Thus the motion of positive and negative ions in an electrolytic solution is a current. Similarly, the motion of electrons is a current.

Free Electrons

The outermost orbital electrons are more loosely bound to the atom than the inner electrons. As they are comparatively free to move away from the atom, they are spoken of as *free electrons*. The motion of free electrons is the most familiar type of current. One ampere of current represents the passage of 6 billion billion (6.3×10^{18}) electrons in 1 second through any given cross section. The cross section may be taken across a solid, as in a wire, across a gas, as in a thyratron, or across a liquid, as in an electrolytic solution. Metals possess free electrons in large numbers and are, therefore, good conductors of electric current.

Potential

Charges move when they are attracted or repelled by other charges and when they have a path through which they can move. Any point which repels electrons, such as a point at which there is a large number of electrons, is considered a point of "negative potential." A point at which there is less than a normal number of electrons is considered a point of "positive potential." Therefore, an electron is repelled from a point of negative potential and is attracted to a point of positive potential. The difference in potential between two points can be defined in terms of the force of attraction or repulsion on an electron. This difference in potential is also called *voltage* or *electromotive force* (*emf.*).

The current that flows through an object depends on the potential applied across the object—that is, on the potential difference between two points. In any one circuit there usually are several points of different potential. It is necessary, therefore, to have some reference point.

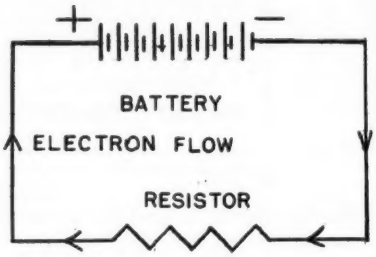


Fig. 1-4. Electron current flow through a resistor connected across a battery.

The earth is so large that it can supply or accept large currents without change in potential. Therefore, it is the most common point of reference potential. Most circuits have one point connected to ground, and all other points in the circuit are then referred to this grounded point of zero potential.

Direction of Current

As the earliest workers in the field did not know about electrons, they arbitrarily assumed that current flows from positive to negative. This direction for current is true only for positive charges such as positive ions. However, the most common current is electron current, which flows from negative to positive, as shown in Fig. 4.

Although many textbooks still consider "current" to flow from positive to negative, most modern books consider current only as electron current, and current flow only from negative to positive.

When the current flows continuously in one direction it is called *direct current* (d.c.). When the current changes direction periodically it is called *alternating current* (a.c.). When the current flows intermittently in one direction, it is called *pulsating direct current*. The *frequency* of an alternating current is one-half of the number of times per second that the current reverses direction.

Current Sources

Direct current can be produced in large amounts (amperes) by converting chemical or mechanical energy into electrical energy. Chemical energy is converted into electrical energy by means of cells, each of which consists of electrodes immersed in an electrolyte. The chemical reaction in the cell causes one terminal (the negative terminal) to have an excess of electrons and the other terminal (the positive terminal) to have a deficiency of electrons.

Cells are divided into two kinds—primary cells and secondary cells. Primary cells use an irreversible chemical reaction which consumes the electrodes. Therefore, primary

Continued on page 796

A Method *for* Correcting Orifice-meter Measurements *for* Flow Pulsations

By E. V. HARDWAY, JR., President, The Beta Corporation, Richmond, Va.

ABSTRACT.—An approximate method for calculating flowmeter errors caused by pulsations in the line is made by (1) expressing the error in terms of differential-head only, (2) expressing the pulsation error in terms of the rms. value of the pulsation and the average value of the differential pressure, and (3) using only the first significant term in the series expression of the error equation. The resultant error expression, which uses only the rms. and average values of the differential pressure, is tested for several waveforms and found to give an accuracy of 1 percent flow up to pulsation errors of about 7 percent. Tentative instrumentation for obtaining the rms. value and for using the method is shown.

Introduction

ACCURATE flow measurement is a necessity in the natural-gas transmission industry, where *one percent* of the annual sales amounts to about ten million dollars. The problem of measuring steady flow to an accuracy within commercially acceptable tolerances has been solved by inferential measurements. A wide variety of carefully engineered flowmeters are commercially available which are fully satisfactory for steady-flow applications. There have been, however, no practical methods or instruments available for the measurement of pulsating flow, or for the quantitative determination of flowmeter errors resulting from pulsations.

On gas transmission lines, flow pulsations arise from the use of reciprocating compressors. Severe pulsations often are reduced by the use of mufflers, pulsation dampeners, or upstream orifices. In many situations, however, it is difficult or impractical to eliminate the pulsations for metering purposes because of the cost of the additional equipment and the resulting increase in required compressor horsepower. This is particularly true when the pulsations are augmented by resonant conditions in the piping.

In nearly all installations the pulsation errors are positive—that is, the measured flow is greater than the actual flow. Hence pulsation errors do not average out over a period of time or multiplicity of installations. More important, the error due to pulsations can exceed commercially acceptable tolerances. This is unsatisfactory not only with regard to the purchase and sale of gas but also with regard to the determination of leakage. An upstream meter near a compressor station can indicate more gas being delivered to the line than is measured at a downstream station which is free from pulsation effects. The meters thus can indicate leakage which does not exist.

Pulsometer.—The "pulsometer" provides a means of relating peak differential pressure to the mean differential pressure in order to determine whether the pulsation error is greater or less than the generally acceptable value of 1 percent. The empirical curve utilized with this instrument is based on data obtained from an extensive test program and checks very closely with the expected theoretical relationships. This commercially available instrument is being used widely for this application. However, the instrument is not generally used to correct the final measurements for the pulsation error, or to determine the magnitude of errors exceeding 1 percent. The reason for this is that the instrument measures only the peak pressure in one direction and, therefore, cannot take into account the pulsation waveform or allow for rapidly fluctuating amplitudes. These effects increase rapidly for errors greater than 1 percent. The problem remains how to measure errors that exceed the acceptable 1-percent value.

The principal difficulty in developing instruments to measure pulsating flow with orifice flowmeters has been the lack of a simple functional relationship between the error due to pulsations and any quantity which can be determined by inferential measurements. As orifice flow meters are in wide usage and provide accurate means of metering steady flow, an auxiliary instrument to indicate or record the quantity required to correct for pulsation errors appears to be the most practical solution. This article presents a relationship between the pulsation error and certain measurable quantities, together with the method of correction and the required auxiliary instrumentation*. The proposed solution to the problem is based on an engineering approach and requires certain assumptions and approximations, which are defined and discussed.

Cause of Pulsation Error

The principal cause of pulsation error is the fact that the meter mechanism cannot follow the rapid pulsations and consequently indicates *average* differential pressure. The square root of the average differential pressure is integrated to obtain total flow. However, the correct flow is proportional to the integrated square root of the *instantaneous* differential pressure, and not the average differential pressure. Some types of insufficiently damped meters have rapid response characteristics and tend to follow the pressure pulsations, thus causing wavy lines on charts. These indications of pulsations are of little use, however, because the dynamic response of the mechanisms does not permit accurate reproduction of the pulsations. Even if the records were accurate, the overlapping or closely spaced lines would, for practical purposes, be non-integrable.

An acceptable inferential-head instrument suitable for measuring pulsating flow accurately must be capable of (1) extracting the square root of the instantaneous pressure differential across the orifice, which might vary rapidly with frequency components from, say, 20 to 100 cps.; and (2) integrating this fluctuating square-root value to an over-all accuracy of two percent.

The most practical approach is to continue to utilize existing flowmeters, which are reliable and accurate for the measurement of average pressure, and to use some auxiliary means to apply a secondary correction for the pulsation error.

Analysis of Pulsation Error

The following analysis applies to orifice-meter installations on gas transmission lines where the differential pressure across the orifice is small in comparison to the absolute static pressure in the line. The analysis is equally applicable to the inferential measurement of the flow of any liquid or gas with an orifice, venturi, or flow nozzle —provided that the conditions are such that the various assumptions regarding the nature of the flow conditions are valid.

The first and most important assumption is that the conventional steady-flow equation is applicable to pulsating flow. The limiting conditions are that if the pulsation waveform is complex, the distance between taps must be short compared to one quarter of the wavelength of the highest important pulsation harmonics. If a bank of reciprocating compressors which are not synchronized are supplying the line, the most severe pulsations occur during intervals when the compressors are approximately in phase, and hence occur at the lowest fundamental frequency. When the compressors are running at different speeds, amplitude beats occur. If they are running in synchronism but out of phase, the nonsinoidal pressure pulses tend to add, producing higher pulsation frequencies

* Patent pending.

but a more even flow with decreased pulsation amplitudes. Although considerable harmonic content is present in the compressor output waveform, the higher frequencies are more easily attenuated in the dampeners and lines. In nearly all meter installations near reciprocating-compressor stations, it is probable that the important pulsation frequencies are between 20 and 100 cps., corresponding to ¼ wavelengths from 12 to 2½ feet. In using the steady-flow equations for gases, therefore, we restrict the applicability of the method to flange and vena-contracta tap-orifice installations, or other installations in which the taps are less than 2½ feet apart. This assumption justifies the use of the steady-flow equation without regard to the partial-derivative terms for acceleration and continuity in Euler's basic dynamical flow equations. This procedure is analogous to the use of conventional "lumped-parameter" components in electrical circuits, which is valid at all except ultra-high frequencies where the wavelengths compare dimensionally to wiring lengths and component dimensions.

Steady-flow equation.—One general form [2] for the steady-flow equation for gases is:

$$W = 359.1\,(D_2)^2\,\alpha K Y_1 \sqrt{\rho_1 h}$$

where:

- W = flow in lbs. per hour
- D_2 = orifice diameter in inches at 60 F.
- α = area multiplier to allow for thermal expansion
- K = orifice discharge coefficient
- Y_1 = expansion factor at upstream conditions
- ρ_1 = upstream density in lb./cu. ft.
- h = pressure differential in inches of water at 60 F.

As K is a function of Reynold's number and, therefore, of the mass flow rate, the value for K obtained by successive approximations using the average flow rate is not exactly correct for pulsating flow. However, by assuming various functions for W, it can be shown that the separately determined value for K (assuming steady flow) generally is better than 1 percent. As the expansion factor, Y_1, is essentially a linear function of differential pressure, the value of Y_1 obtained from the average differential pressure is correct. In view of the above, the equation may be rewritten as:

$$W = C\sqrt{\rho_1}\sqrt{h},$$

where $C = 359.1\ (D_2)^2 \alpha K Y_1$

The terms $\sqrt{\rho_1}$ and $\sqrt{h}$ are separated because they are measured independently.

Under conditions of pulsating flow, both $(\sqrt{\rho_1})_{av.}$ and $(\sqrt{h})_{av.}$ are less than $\sqrt{\rho_{1av.}}$ and $\sqrt{h_{av.}}$, with the result that the measured value of flow is greater than the actual flow. The "average" subscripts on the expressions refer to the averaging done by the meter and in the integration of the chart. This averaging is done over time intervals which appear as short distances on the chart, but which are long compared to the lowest pulsation period.

If the density fluctuations are small in comparison with the velocity and differential-pressure fluctuations, it may be assumed that $(\sqrt{\rho_1})_{av.}$ is approximately equal to $\sqrt{\rho_{1av.}}$—again with the averages taken over short intervals. The quantity actually measured is P_1, the upstream line pressure. Although the relation between P_1 and ρ_1 is linear for small changes at constant temperature, the relationship is adiabatic at pulsation frequencies, which further tends to reduce the effect of density pulsations. As the density is independently determined from metered pressure and temperature in actual flow-measuring operations, the correction obtained from considering the $\sqrt{h}$ term cannot be large inasmuch as both effects tend to increase the ratio of measured flow to actual flow.

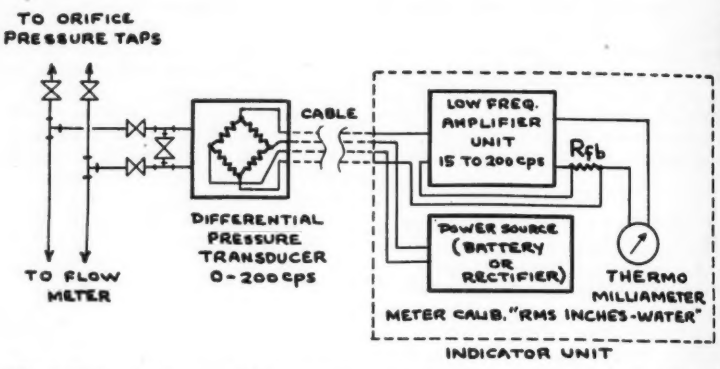


Fig. 1. Instrument for measuring rms. value of the fluctuating component of the differential pressure.

Under the stated conditions, however, and in view of past experimental evidence—where theoretical and experimental data checked on the basis of considering $\sqrt{h}$ alone—it is reasonable to consider the density term as having a minor effect except for extreme pulsation conditions.

Reducing the equations to the simplest forms for consideration of average values over short-time intervals:

$$W(\text{meas.}) = C_o\sqrt{h_{av.}}$$

$$W(\text{actual}) = C_o(\sqrt{h})_{av.}$$

Error ratio.—The *error ratio* due to pulsations is:

$$E_R = \frac{W(\text{meas.}) - W(\text{actual})}{W(\text{meas.})} = \frac{\sqrt{h_{av.}} - (\sqrt{h})_{av.}}{\sqrt{h_{av.}}} = 1 - \frac{(\sqrt{h})_{av.}}{\sqrt{h_{av.}}}$$

By defining new terms, this relation can be put in a more general mathematical form as follows:

Let h_P = pulsating component of differential pressure

Then, $h = h_{av.} + h_P$.

And,

$(h_P/h_{av.}) = f(t)$ = a function of time which may vary between -1 and $+1$ in amplitude.

As $h = h_{av.}[1+f(t)]$, the error ratio may be written as:

$$E_R = 1 - \left(\sqrt{1+f(t)}\right)_{av.}$$

or:

$$E_R = 1 - \frac{1}{T}\int_0^T \sqrt{1+f(t)}\ dt,$$

where T is the fundamental period of the pulsation, which may vary continuously without affecting the defined relationship. The problem now is to obtain E_R in terms of measurable quantities.

An Approximate Expression for Pulsation Error

Using the binomial theorem, the function $\sqrt{1+f(t)}$ can be expanded as follows:

$$\sqrt{1+f(t)} = 1 + \frac{1}{2}f(t) - \frac{1}{8}f^2(t) + \frac{1}{16}f^3(t) - \frac{5}{128}f^4(t) + \cdots$$

This expression can be integrated term by term to obtain the average value. However, it is evident that the second term can be dropped by definition of the average pressure, i.e.:

$$\frac{1}{T}\int_0^T f(t)\,dt = \frac{1}{T}\int_0^T \frac{h-h_{av.}}{h_{av.}}\,dt = \frac{h_{av.}-h_{av.}}{h_{av.}} = 0$$

The fact that this term can be dropped makes it possible to derive the simplified expression for pulsation error which follows.

The coefficients become small for the higher order terms but do not approach zero. For relative pulsation amplitudes less than unity the $f^n(t)$ terms approach zero for higher values—that is, $f^n(t)$ approaches zero as n approaches infinity.

We now arbitrarily drop the cubed term because of the small coefficient and the fact that it is an odd-order term. When $f^3(t)$ is expressed as a Fourier series, the average value of the odd harmonics becomes zero. To contain even harmonics, f(t) must be asymmetrical. It will be shown, however, that good results can be obtained even with a substantial amount of asymmetry—for example, where the pressure varies with $\sin^2\left[\frac{2\pi t}{t}\right]$, corres-

ponding to sinoidal velocity fluctuations in the orifice. The justification is the same for all odd terms. The higher order even terms are dropped because of their decreasing magnitude. It is now possible to define a new term E'_R which is approximately equal to E_R for small values of $f(t)$:

$$E'_R = 1 - \frac{1}{T}\int_0^T \frac{1}{8}[1 - f^2(t)]dt$$

$$E'_R = -\frac{1}{8}\int_0^T \frac{h_p^2}{h^2_{av.}}dt$$

$$E'_R = -\frac{1}{8}\frac{(h_p^2)_{av.}}{h^2_{av.}}$$

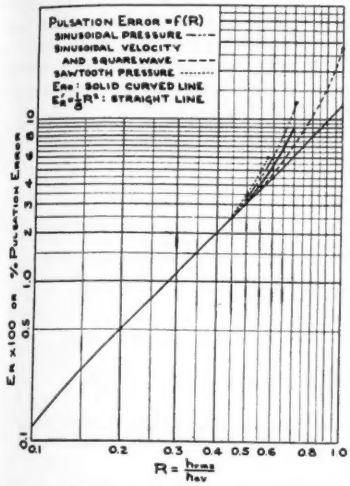

PULSATION ERROR = f(R)
SINUSOIDAL PRESSURE
SINUSOIDAL VELOCITY AND SQUARE WAVE
SAWTOOTH PRESSURE
ER: SOLID CURVED LINE
E'R = 1/8 R²: STRAIGHT LINE
ER x 100 OR % PULSATION ERROR
R = hrms / hav

Fig. 2. Pulsation error (E_R) as a function of ($h_{rms.}/h_{av.}$) (R) for (1) sinoidal differential-pressure pulsations, (2) sinoidal velocity pulsations, and (3) symmetrical saw-tooth pressure pulsations.

The root-mean-square value of h_p is $\sqrt{(h_p)^2_{av.}}$, or $h_{rms.}$. Therefore, the error may be written:

$$E'_R = \frac{1}{8}\left[\frac{h_{rms.}}{h_{av.}}\right]^2 = \frac{1}{8}R^2$$

where R is defined as $h_{rms.}/h_{av.}$.

We have now shown that an approximate expression for pulsation error can be related to $h_{av.}$, which is always a known metered quantity, and $h_{rms.}$, which is the root-mean-square value of the *fluctuating component* of differential pressure. The quantity $h_{rms.}$ can be measured with suitable instrumentation (Fig. 1) described later. It is first desirable to test the derived expression for several radically different waveforms.

To evaluate the usefulness of the expression E'_R in a general way for any type of complex waveform is an almost impossible task. It is reasonable, however, to make comparisons between E_R (the correct error ratio) and E'_R (the approximate expression derived above) for a variety of assumed waveforms, some of which are rich in harmonic content. If E'_R holds for several radically different types of waveforms, it is logical to assume that it holds for waveforms found in practice. No complete mathematical derivations are given here as they are somewhat long and have but little bearing on the subject matter.

(1) *Sinoidal Differential-pressure Fluctuations.*

$$E_R = 1 - \frac{2}{\pi}\sqrt{1+\sqrt{2}R}\;E\left[\begin{matrix}\pi \\ k, \\ 2\end{matrix}\right]^*$$

where: $k = \sqrt{\dfrac{2\sqrt{2}R}{1+\sqrt{2}R}}$

$$R = \frac{h_{rms.}}{h_{av.}}$$

The values of E_R as well as the values

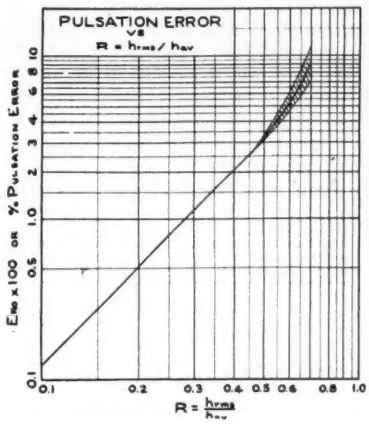


Fig. 3. Instrument curve of pulsation error vs. R chosen to minimize method error at upper range of method.

of the special cases which follow are plotted in Fig. 2.

(2) *Sinoidal Velocity Fluctuations in Orifice.*

It is simpler in this case to determine implicit relationships between E_R and R. If U, the velocity, and the relative velocity λ_U are defined by $U = U_{av.}[1+\lambda_U \sin\frac{2\pi t}{T}]$, where λ_U has any value from zero to unity, we may write the implicit expressions relating E_R and R in terms of the variable "m":

$$m = \sqrt{1+\frac{\lambda^2_U}{2}}$$

They are:

$$E_R = \frac{m-1}{m}$$

$$R = \sqrt{\frac{(m^2-1)(m^2+7)}{2m^4}}$$

By substituting arbitrary values for "m", E_R is found as a function of R. The results are plotted in Fig. 2. This case is of interest because the pressure waveform is asymmetrical with second harmonic content up to 25 percent of the fundamental.

(3) *Square-wave Velocity (and Pressure Pulsations.*

For symmetrical square waves both the pressure and velocity have the same wave form and $h_P(max) = h_{rms.}$

$$E_R = 1 - \tfrac{1}{2}[\sqrt{1+R} - \sqrt{1-R}]$$

(In the example of the square wave, the third-harmonic content is large, amounting to one-third of the fundamental.)

(4) *Saw-tooth Waveform.*

$$E_R = 1 - \frac{1}{\sqrt{3}R}[(1+\sqrt{3}R)^{3/2} - (1-\sqrt{3}R)^{3/2}]$$

In Fig. 2, E_R is plotted as a function of R (a measurable quantity) for sinoidal differential-pressure pulsations of both pressure and velocity, and symmetrical saw-tooth pressure pulsations. E'_R appears as a straight line on the log-log plot. The curves terminate at the point where velocity reversals occur in the orifice and, consequently, where the method is no longer applicable.

A deviation from the E'_R curve for large errors is expected because of the series terms which were dropped. It is possible, however, to choose an instrument curve which lies approximately midway between the derived curves, and to define this arbitrary function $E_{RO} = f(R)$ as the approximate error function for use in making corrections to the measured flow.

It is of significance that the curve for E_{RO} lies within 0.5 percent of the derived curves for errors up to 5 percent and within 3 percent for errors up to 9 percent, neglecting the symmetrical-sawtooth pulsation curve.

Fig. 3 is essentially the same plot with the instrument curve E_{RO} plotted, and the derived curves merely defining the estimated margin for error in the use of the plot. When R is determined as being greater than 0.65, corresponding to an error of 7 percent, the margin for error is greater than 1 percent and it may be concluded that the pulsations must be reduced for accurate measurements to be possible.

Method of Correction for Pulsation Error

The steps to be followed in correcting the measured flow to obtain actual flow are as follows:

(1) $h_{rms.}$ is determined from the indication of suitable instruments later described. ($h_{rms.}$ is measured in terms of inches-water.)

(2) "h" or $h_{av.}$ is obtained directly from the indications of the flowmeter in inches-water.

(3) R is obtained by dividing $h_{rms.}$ by $h_{av.}$.

(4) Using a chart similar to Fig. 3, E_{RO} is obtained as a function of R.

(5) The correct value of flow or flow rate is obtained from:

$W(actual) = W(meas.) - E_{RO}\,W(meas.)$

$Q(actual) = Q(meas.) - E_{RO}\,Q(meas.)$

These operations must of course be applied over periods where the flow conditions are reasonably constant. If over a period of, say, 24 hours the pulsation and flow conditions remain

Continued on page 774

* Complete elliptic integral of the second kind. In Jahnke-Emde's tables (P. 85, 1945 Ed.) the values of $E(k,\phi)$ are found in terms of α and ϕ where $K = \sin\alpha$.

Comparison *of* Methods *for* Measuring Temperature *of* Molten Metals

By J. W. PERCY, Research Laboratory, United States Steel Co., Kearney, N. J.

EVER since the invention by Dr. Siemens of the forerunner of the present open-hearth furnace, it has been apparent that the temperature of the molten metal is important in the steel-making process. With the increase in our knowledge of physical metallurgy, it has become essential to know as accurately as possible the open-hearth or electric-furnace bath temperature, ladle temperature, and frequently the teeming or pouring temperature.

History

The human eye was undoubtedly the first molten-metal pyrometer. The use of colored spectacles may have aided the melter in judging temperatures. The use of a steel rod about ¼ inch in diameter dipped into a spoonful or stream of hot metal also gave a fair indication of temperature. This latter idea still is used to some extent, especially in foundries.

The optical pyrometer.—In 1864, the French physicist Becquerel suggested a form of photometer which could be used as an optical pyrometer, but apparently never constructed it. In 1892, Le Chatelier used the idea and constructed the first "optical." With it he made temperature measurements in the blast furnace, coke ovens, and Siemens-Martin furnace—our open hearth. His source of comparison was an amyl-acetate lamp. About 1901, Wanner built an instrument using a 6-volt electric lamp for his standard source. In Germany in 1901, Holburn and Kurlbaum developed a simple and efficient optical pyrometer using an electric lamp as a standard. This instrument was the first modern optical pyrometer.

In 1902 in this country, Norse was granted three U. S. patents on his "Thermogauge." In 1917, Dr. Burgess, who with others was determining the emissivity of various metals and oxides, suggested that a value of 0.4 be used for the emissivity of liquid iron and steel for wavelength of 0.65. This suggestion was incorporated later in the Leeds & Northrup optical pyrometer, and a direct-reading pyrometer for liquid iron and steel came into being. By 1923 this pyrometer was being used rather widely in the steel industry. Other manufacturers offered optical pyrometers based largely upon European developments.

Recent observations indicate the Burgess value of 0.4 emissivity is low, and that the value is probably about 0.42 at 2750 F., increasing to 0.50 at 3000 F. for carbon steels and to as high as 0.70 at 3000 F. for some grades of stainless. Despite its limitations, the optical pyrometer has proved to be a very valuable instrument and has done much to improve the steel process.

Platinum vs. platinum-rhodium thermocouple.—In 1929, the Iron and Steel Institute of Great Britain appointed a sub-committee to investigate and report on the various methods of molten-metal temperature measurements. They investigated the Fitterer thermocouple (tungsten-silicon carbide), the platinum 13% rhodium vs. platinum thermocouple, and the optical pyrometer. The sub-committee discontinued work on the Fitterer couple because they were unable to obtain them from the United States. In 1937, Schofield and Grace reported that both the optical pyrometer and the platinum-rhodium vs. platinum thermocouple could be employed. In 1939, they introduced the device shown in Fig. 1, upon which all of the quick-immersion couples now used appear to be based. In 1935, some work was done by the Research Laboratory of the United States Steel Corporation using the Fitterer and also the platinum-rhodium vs. platinum couple. At that time, this work was of very little interest to the open-hearth operators, and was not considered practicable.

Blow-tube pyrometer.—In November 1935, Collins and Oseland of Carnegie-Illinois Steel Corporation were granted U. S. Patent No. 2,020,019 for a device by which they measured hot-metal temperatures by means of an optical pyrometer sighted through an air-purged open-end tube (Fig. 2). Upon this device are based the two so-called "dunker," or blow-tube, type of pyrometers now in use. Leeds & Northrup, licensed under the patent, make use of a special radiation unit placed in the purged tube. The second type, developed by the Research Laboratory of the United States Steel Corporation, and now made and marketed by the Brown Instrument Division of Minneapolis-Honeywell, uses a Photronic cell at the outside end of an air-purged tube.

Immersion Thermocouples

Two types of immersion thermocouples are being sold commercially at present. The type made by Leeds & Northrup has a straight head (Fig. 3). The assembly is fairly rugged and is expected to last for many hundreds of readings. The second type, which is made by Brown, has a 60-degree or 90-degree bent head (Fig. 4). Both types employ a short fused-silica tube as protection for the thermocouple. This tube is cemented into a carbon plug, which is taper-fitted into the assembly head.

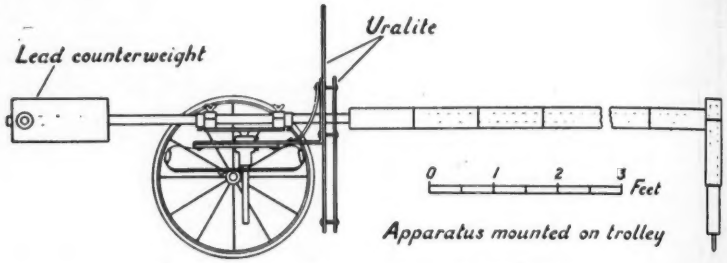


Fig. 1. Schoefield and Grace open-hearth thermocouple.

Some users find it cheaper to build their own assemblies, such as the one in Fig. 5.

Some models store several feet of thermocouple wire in the head and withdraw a few inches at a time as needed. Others use short couples and replace them entirely. Almost all types use extension wire from the head or junction through the handle, and from the handle to the recording instrument. A few use a permanent platinum+rhodium-platinum extension from the junction through the handle.

A few words of caution are necessary. The standard extension wire now in use—copper and copper-nickel alloy—gives good temperature compensation up to 250 F. or a correction within ±12 F. at 400 F. ambient. Tests have shown that if a quick-immersion couple is immersed in the open-hearth bath for 25 seconds and then withdrawn, the head at the junction of the thermocouple and extension wire reaches 400 F. about 10 seconds later, or 35 seconds after the couple entered the bath. In about 55 seconds the head is at 1000 F. and requires 35 *minutes* more in moving air to return to 400 F. To be on the safe side, no quick-immersion couple using extension wires of copper and copper-nickel alloy should be used more often than once an hour, even though it takes but a few seconds to change the silica-tube tip.

Not long ago an unidentified writer in the Journal of Metals made the flat

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statement that "off-calibration couples are never found in the melt shop." That statement is a bit ambiguous. If he meant that platinum-rhodium vs. platinum couples never become contaminated in the melt shop, he left himself open for argument. It is not unusual to find couples off calibration by 15 F. or more after 5 or 6 immersions. The main trouble seems to come from sulphur in the oil and grease inside new pipe. For a long time it

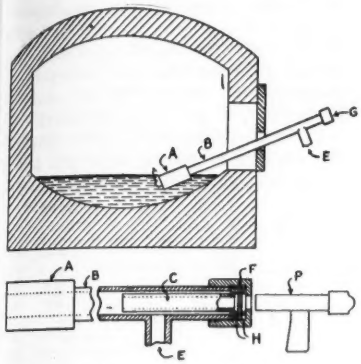


Fig. 2. Collins and Oseland blow-tube pyrometer.

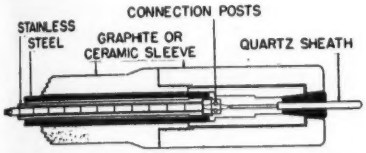


Fig. 3. Leeds & Northrup immersion-thermocouple head.

was thought to be the carbon, but recent observations indicate that the sulphur forms a silica sulphide. This compound attacks the rare metals to form one or more platinum silicides, which contaminate the couple and cause low readings. Therefore, it is necessary to burn off all the oil and grease in new pipe and to keep all oil and grease away from platinum. As a further protection, some plants are making use of a stainless-steel plug to replace the carbon.

Records.—Quick-immersion thermocouple systems record the temperature on a strip-chart or on a round-chart high-speed potentiometer of the electronic type. In one instrument an elaborate system of 3 signal lights indicate that (1) the thermocouple circuit is completed, (2) the thermocouple is operating, and (3) the maximum temperature has been reached. These gadgets make it possible for the operator merely to watch the signal lights in order to take a bath-temperature reading.

Operating procedure.—If the reading is taken through a wicket hole, a 60-degree angle head or a straight head is preferable to a 90-degree bend. Care must be taken not to break the silica tip. The tip must be immersed below the slag and into the metal. The operation should be completed in 25 to 30 seconds and the head withdrawn. Only one reading can be taken on a

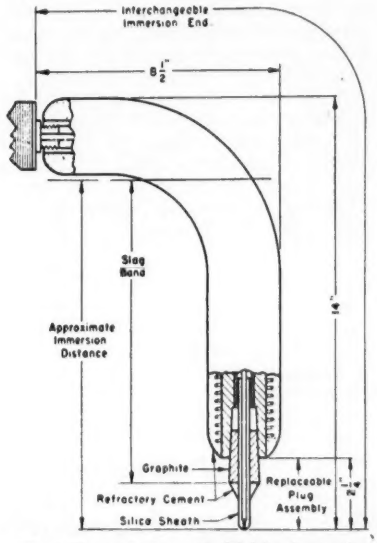


Fig. 4. Brown Instruments Division immersion-thermocouple head.

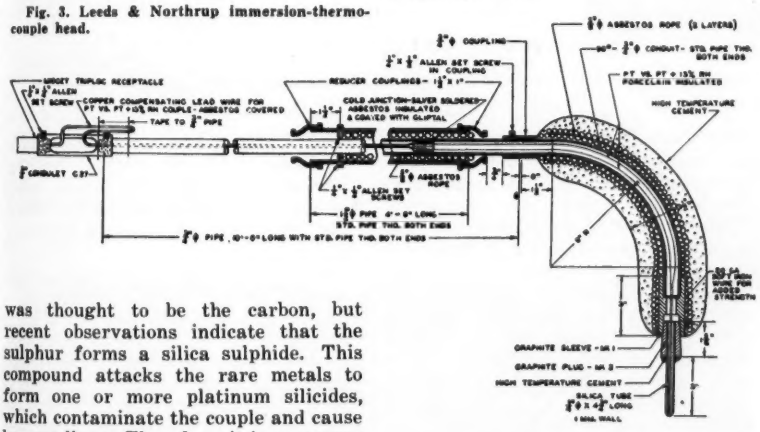


Fig. 5. Individual plant design for an immersion thermocouple.

silica protection tube, but 4 to 6 readings can be made with a single platinum couple. A recorder should be provided for every two or three furnaces. About four to five thermocouples assemblies are needed for each furnace. Satisfactory maintenance requires at least 8 man-hours per day for each five furnaces, allowing two readings per heat.

Each thermocouple assembly weighs about 35 to 50 pounds, depending on the design. Although an assembly can be handled by one man, operators usually prefer to use two men to keep tips from being broken.

Blow-tube Pyrometers

The two types of blowing-tube molten-metal pyrometers now sold commercially are based on the original patent granted to Collins and Oseland. The type made by Leeds & Northrup makes use of a small radiation unit placed well down in the air-purged tube (Fig. 6). The type made and sold by Brown, as developed by the Research Laboratory of United States Steel Company, employs a Photronic cell placed at the outer end of the purged tube. (Fig. 7). The former measures the total radiation through a silica lens as an indication of temperature; the latter measures the brightness of the molten metal in the visible range.

The tubes which form the bodies of these devices are seamless tubing about 2 inches in diameter and about 7 feet in length. The assemblies weigh 50 to 60 pounds. As they require a small-diameter air hose for the purge air or gas, they are a bit more difficult than the thermocouple to maneuver. To prevent the slag from sticking to the tube, Leeds & Northrup recommend the use of a cardboard cylinder slipped over the tube. The same thing can be accomplished by coating the outside of the purge tube with a thin layer of ordinary mold coating, or "dope", which contains bentonite. One coating lasts for a number of readings.

To take a reading, (1) the purge air is turned on, (2) the tube is inserted through the wicket hole and dipped quickly into and out of the slag to form a protective coating, and then (3) the tube is dipped below the interface of molten metal and slag for about 7 seconds to obtain the temperature. After removal from the wicket hole, the slag can be removed easily, and in a few minutes another reading can be taken. With ordinary care, a single tube can be used indefinitely. As many as 1000 readings have been made with no damage to the tube. The Research Laboratory of the United States Steel Company has one tube which has been in use more than five years with very minor repairs. Any slight warpage of the tube can be removed by rotating it for each successive reading.

Comparison of Operation Factors

Thermocouple assemblies have an advantage over radiation assemblies of 10 to 20 pounds less weight, but they have the disadvantage of a fragile silica tip, which is easily broken. The thermocouple must have some maintenance after each reading, and each assembly can be used but once an hour. This necessitates about four assemblies per furnace. On the other hand, one blow-type pyrometer suffices for three or more furnaces and can be used every 15 minutes if necessary. Blow-tubes require but little maintenance, which is probably the reason why they usually get none until they give a bad reading.

If the instruments are used in the proper manner, if they are kept clean, if sufficient maintenance is provided,

and if the operators use common sense, both thermocouple and radiation systems can be used satisfactorily.

Accuracy.—If the protecting silica tip extends at least 3 inches beyond the plug, if the temperature of the head or junction of the thermocouple is not over 200 F., and if the couple is not contaminated, then the probable error should be not more than ± 7 F. As working-temperature ranges in the open-hearth or electric-furnace shop are ordinarily set at about ± 20 F., the probable error in either the quick-immersion couple or the blow-tube is well within the required range.

The blow-tube tends to give high readings because of the oxiding effect of air used as a purge. This oxidizing effect can be taken care of either in the calibration or by use of a nitrogen or argon purge. If nitrogen or argon are used, the readings are true.

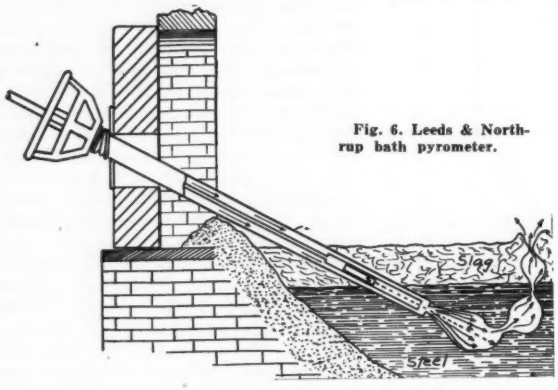


Fig. 6. Leeds & Northrup bath pyrometer.

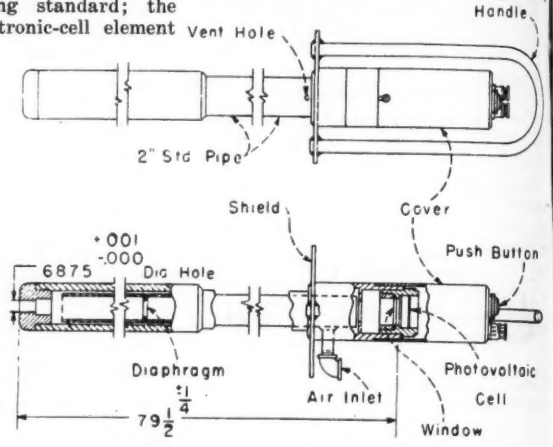


Fig. 7. Brown Instruments Division bath pyrometer.

The absolute accuracy of the thermocouple is established by comparison with standard thermocouples, preferably calibrated at the Bureau of Standards. Blow-tube accuracy is determined by comparison with a suitable standard —a second Rayotube sighted on a hot body for the Leeds & Northrup instrument, and a standard brightness provided by a standard lamp for the Brown. Either type can be checked by sighting against a hot furnace roof if the roof temperature is being measured by a suitable roof-temperature control.

Reliability.—Reliability is probably the reason for the present popularity of the quick-immersion thermocouple. The fact that the silica tip must be replaced after each reading means that the thermocouple is examined. This leads to a high order of reliability. However, in the few shops where the blow-tube has received some maintenance—usually nothing more than a cursory examination of the orifice after each reading, or removal of occasional splinters, and a calibrating check once or twice a week—it too has shown reliability as high as that of the thermocouple.

Availability.—The availability of any of the three systems is partly dependent on maintenance and supervision. The thermocouple assembly must be inspected and the tip changed after each reading. After about five readings the thermocouple must be removed from the assembly, checked, and usually discarded. After 100 to 200 readings, some repairs have to be made on the assembly itself. For these reasons each thermocouple assembly is out of service for about 50 percent of the time.

With a small amount of maintenance, the availability of the blow-tube pyrometer is very high, on the order of 95 percent. Where it has shown poor availability, it has received no maintenance whatever. It appears certain that, given adequate maintenance, the availability of the blow-tube is greater than that of a thermocouple assembly.

Initial cost.—The cost of initial investment plus installation varies slightly from plant to plant. A single-unit blow-tube pyrometer using a radiation unit as the pickup costs about $3,200 including a checking standard; the type using the Photronic-cell element costs about $2,200 including the checking standard. A single-unit quick-immersion thermocouple including four thermocouple assemblies costs from $1,800 to $2,100, depending on the number of gadgets such as signal lights and "howlers." If one were equipping a ten-furnace open-hearth shop, allowing one recorder for each two furnaces, and either fifty thermocouple assemblies, or twelve blow-tubes, with the necessary racks or storage cabinets, piping, wiring, and labor, he might spend from $18,000 to $25,000 for a blow-tube system and from $17,000 to $20,000 for a thermocouple system. Those who can design and construct their own thermocouple assemblies can provide a set-up for about $10,000.

Operating cost.—Another factor is the *cost per reading*. Assuming two readings per heat, the cost per reading is not likely to be more than four cents per ton. For the blow-tube pyrometer, accurate records based on more than 10,000 readings show a figure of about 10 cents per reading for air purge. One plant which for extreme accuracy uses a nitrogen purge, found a cost of 60 cents, of which 46 cents was the cost of the nitrogen. The Research Laboratory tests using nitrogen showed about a third of that value. Another plant which kept a very accurate record, including depreciation of all equipment, showed a cost of 80 cents for an air-purge system. This seems to be high. Thermocouple readings are more costly. The lowest is about 77 cents, and this is in a plant where silica tips are purchased in lots of 1000 pieces at $125.00. This value seems to be low, as the average is about 90 cents. The cost is $2.60 in one electric-furnace plant, where some of this high cost admittedly is due to high breakage of tips and a high machining cost on a special experimental plug. Based on a low of 15 cents for the blow-tube, a thermocouple reading at 77 cents is about 400 percent more expensive.

It is a debatable subject whether one method is better than the other. From the viewpoint of management, which looks for accuracy, reliability, low initial cost, low cost per reading, and low maintenance, without too much concern for weight, one of the blow-tube types fill the requirements very nicely.

From the viewpoint of the superintendent of the open hearth, either system may be satisfactory. If he is charged with all the costs, materials, labor, and day-to-day maintenance, he is likely to choose the same system as the manager—that is, one of the blow-tube system. On the other hand, if part of the costs of materials and labor are charged to another department, or if he has the good will of his melters and first helpers strongly in mind and is not concerned with an additional cost of 3 to 4 cents per ton, he probably will adopt the quick-immersion thermocouple.

The melter or first helper is more concerned with the physical effort or labor involved. The easiest way is for him the only way. As cost or maintenance is secondary to him, he is likely to pick the quick-immersion thermocouple because it is twenty pounds lighter in weight and has only two small wires connected to it.

A Thermocouple System *for* Molten-metal Temperature Measurement

By L. H. VEIOCK, Heppenstall Company, Pittsburgh, Penna.

General

AN ACCURATE, dependable method of measuring the temperature of the liquid steel in the open-hearth furnace has been needed for many years. As early as 1920, attempts were made to measure liquid-steel temperatures. Considerable interest was aroused in bath-temperature pyrometry in 1933, when Dr. G. R. Fitterer reported satisfactory results using his design of the carbon vs. silicon-carbide type of immersion thermocouple.

The rising cost of labor and material, the demand for higher-quality steels, the closer adherence to special alloy-specifications, and the longer furnace and mold life, all make good temperature-measuring equipment a "must" today.

Specifications.—The specifications for molten-metal temperature-measuring equipment are very severe. The immersion unit must be light enough to be handled by one man. It must be portable, so that it can be stored at some convenient location away from the charging floor in front of the furnace, and yet be capable of withstanding average steel-mill conditions such as dust, shock, and vibration. The thermocouple assembly should be constructed to give fast and accurate temperature readings, with a minimum of time between successive immersions. The use of the equipment should not require any special knowledge of pyrometry or Instrumentation on the part of the operator. Above all, the equipment must be more accurate than the Melter's eye, which is sometimes called the original optical pyrometer.

Basic techniques.—The two basic types of liquid-steel temperature-measuring devices in use today are (1) the noble-metal thermocouple, and (2) the radiation unit, or blow-tube type. The immersion thermocouple using a curved head assembly (Fig. 1) is the type now in use in the Heppenstall acid open-hearth shop. The straight-head type is now undergoing tests. The basic design of both types is the same.

Thermocouple construction.—The hot junction of the platinum versus platinum + 13-percent rhodium thermocouple is protected from the molten metal by an expendable thin-quartz closed-end tube. This tube is cemented inside a small graphite tapered plug. The head assembly is made of graphite segments supported in position by a small-diameter iron pipe. The body consists of two thin-wall tubes welded to a common fitting at one end only. The space between the tubes is filled with silo-cel insulation. The outer tube is wrapped with wire over ¾ of its length to give protection against flame.

The rubber-covered thermocouple-extension lead-wire is brought out of the body through a friction-clamp fitting and a protecting spring, and is soldered to a polarized plug. The socket for this plug is soldered to extension lead-wire in conduit and terminates at the Leeds & Northrup Speedomax recorder.

Presented at the Conference "Instrumentation for the Iron and Steel Industry," sponsored by the Carnegie Institute of Technology and the Pittsburgh Section, Instrument Society of America, March 28 and 29, 1951, Hotel Roosevelt, Pittsburgh, Penna.

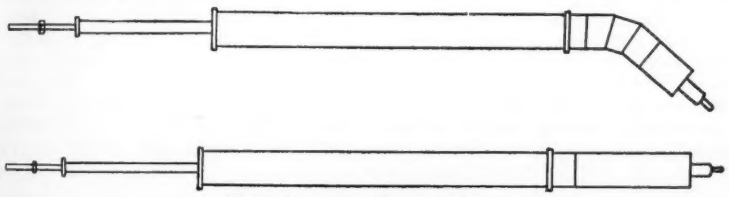


Fig. 1. Immersion thermocouples.

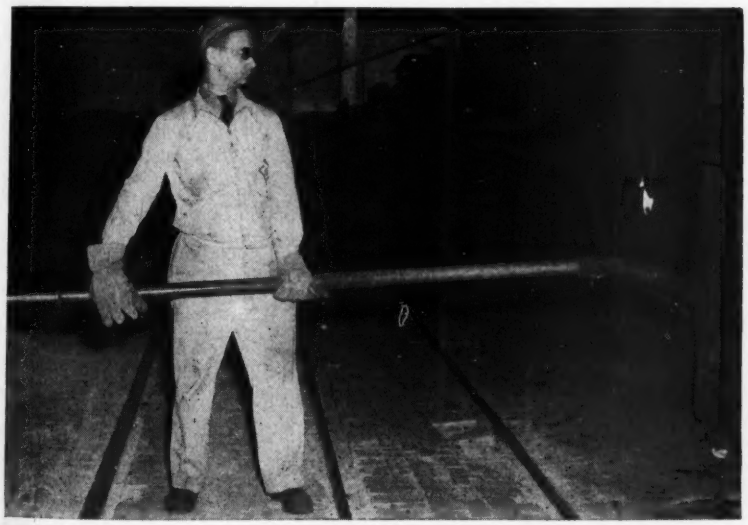


Fig. 2. Removing thermocouple from furnace.

Using the Thermocouple Recorder

To take the first temperature-reading of a heat, the procedure is as follows:

1. Connect the polarized plug to the socket in the floor.

2. Turn the recorder power-switch to the "ON" position. When the vacuum tubes in the amplifier have reached operating temperature, the pointer will indicate somewhere between 0 and 200 degrees F.

3. Standardize the recorder by pushing the small black knob on the left side of the instrument door; turn clockwise and hold in this position until the indicator stops moving. Release the knob; then repeat this operation until there is no further movement of the pointer.

4. Tighten the quartz-tube graphite plug in the immersion-head assembly.

5. Check the tip of the thermocouple either by heating the tip of the quartz tube with a match, or by holding the tip of the unit near the wicket hole in the furnace door, until the pointer of the recorder starts upscale and the green indicating-lamp on the instrument panel is lit. If the recorder does not show a temperature rise with this test, the immersion unit should be returned to the Instrument Shop for examination. This eliminates the possibility of using a unit which may be shorted or faulty.

6. Insert the immersion unit through the hole in the center of the furnace for a distance of approximately 4.5 feet, pushing the head assembly through the slag into the metal, and keeping the body just above the slag level.

7. When the maximum temperature has been recorded, the instrument alarm will sound. Remove the head from the metal and withdraw the immersion unit from the furnace as quickly as possible (Fig. 2). The total time of immersion

Fig. 3. Removing plug from thermocouple head.

should be from 20 to 30 seconds. Place the immersion unit on the cooling rack. Remove the lead-wire plug from the socket. The slag clinging to the head assembly after removing from the furnace cracks when cooling, which makes the slag easy to remove.

8. Remove lead-wire plug from socket.

9. Open recorder door and make notations on the chart. Each reading is identified by heat number, grade of steel, time of reading, date of reading, identifying number of the immersion thermocouple, and the name or initials of the person taking the reading.

10. After a few minutes, the slag can be removed easily from the head (Fig. 3) and the plug replaced with a new one. Do not leave the platinum wire exposed; always replace the tip as quickly as possible.

DETAILS OF IMMERSION THERMOCOUPLE.

The immersion thermocouple is made of 3 units—the head assembly, the body, and the thermocouple, including extension lead wire.

The head (Fig. 4) is made of four graphite segments, which are fitted together in fish-spine fashion over standard ⅜-in. iron pipe. This permits the head to expand and contract with heating and cooling without danger of breaking or letting the liquid metal penetrate the pipe and come in contact with the thermocouple. The 13.5-in. length of pipe is well burned with a torch before assembling to burn off any foreign material such as cutting oil, loose scale, etc. The pipe then is cleaned out with a wire brush to remove scale and dirt. A graphite collar is mounted between the head and body to cover the lock assembly, which anchors the head to the body. The nose segment has a tapered hole to accommodate the plug and quartz tip. The quartz closed-end tube extends 1.5 inches from the graphite plug and is cemented in place with "Sillimanite Air-Set" cement. The tapered end of the plug also is covered with "Sillimanite" to reduce the possibility of contamination resulting from exposed graphite.

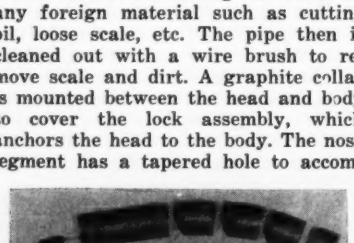


Fig. 4. Details of curved-head assembly.

The body is made of 2-in. O.D. 0.065 wall tube, 6 feet long. It is welded at the head end to a washer, to which is welded a 9-ft. length of 1-in. O.D. light-wall tubing. The two tubes are separated by 5 small spacers, and the space between is filled with silo-cel insulation. The opposite end of the 2-in. tube is welded to a washer, which floats free over the 1-in. tube. This makes a good expansion joint to allow the outside tube to expand longitudinally without breaking the weld on the inside tube. A layer of 12-gage low-carbon wire wrapping over the outer tube offers additional protection against flame impingement by retarding the burning effect of the tubing. This wire wrap is removed and replaced after it becomes badly burned, making the body usable for another 80 to 100 immersions. A 9-ft. 8-in. length of ⅜-in. iron pipe is placed inside the body to accommodate the thermocouple assembly from the head, and also to provide constant tension for the head segments. There is a spring-and-adjusting-nut device for setting the head tension. The small set-screw anchors the keyway which keeps the head assembly from turning, but allows it to expand and contract.

The platinum versus platinum+13% rhodium thermocouple is soldered to rubber-covered heavy-duty extension lead wire. Small-diameter double-bore porcelain insulators are used for the entire length of the couple. The hot junction is exposed for approximately 3/16 inch. This is done by grinding the sides of a 2-hole insulator to leave the wire exposed and yet provide insulation between the wires. This method of protection results in increased speed of response while retaining the advantage of mechanical protection for the hot junction. The weld of the couple is kept about ⅛ inch from the quartz tip to prevent the possibility of the platinum adhering to the quartz in case of softening of the tip due to an extremely high temperature.

Lead-wire location. — One of the major problems is to determine the proper location for the extension lead-wire connection to the thermocouple. If the immersion unit is allowed to cool to room temperature before being used again, thermocouples of relatively short lengths can be used. Sometimes, however, the thermocouple must be ready for use after rather short periods of cooling, during which time the unit may not be cooled to room temperature. Therefore, a series of tests were conducted to determine the temperature gradient in the body of our immersion unit. Fig. 5 shows a temperature-gradient curve of an average immersion unit. The readings were taken by mounting three 20-gage iron-constantan thermocouples in the inside pipe at

Continued on page 794

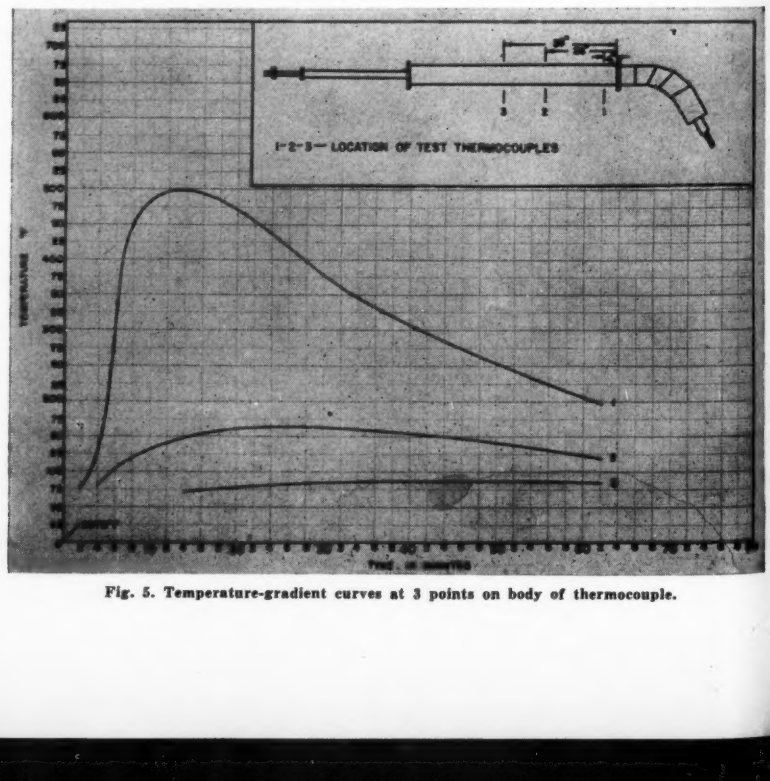
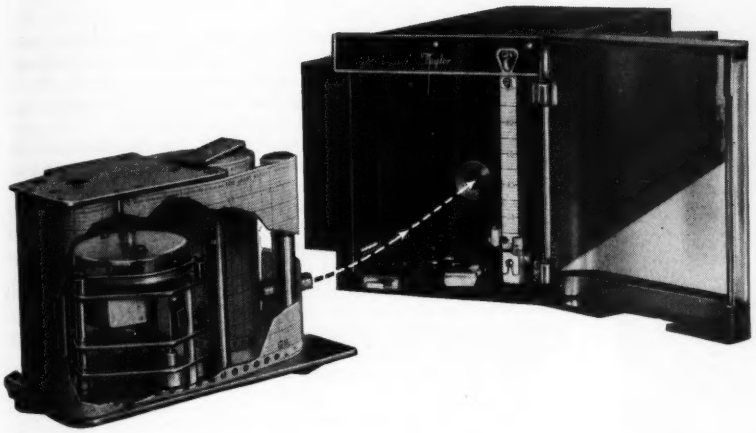
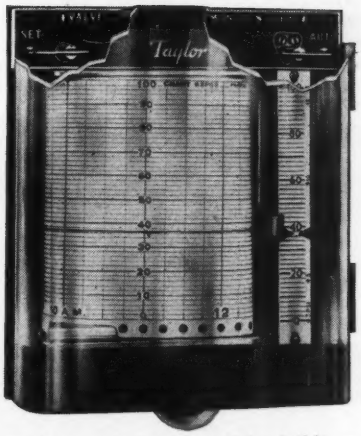


Fig. 5. Temperature-gradient curves at 3 points on body of thermocouple.

PNEUMATIC CHART DRIVE FOR HAZARDOUS ATMOSPHERES

on Taylor's TRANSET Recorder*





A 3-hour continuous record is visible on this thirty-day rectilinear strip chart. This TRANSET Recorder fits 4⅜" x 5" panel space, with automatic-manual unit, remote set point adjustment, valve position indicator—all with unmatched accuracy and dependability.

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INSTRUMENTS ON THE MARCH

Analog Computer

BOSTON, Mass.—An analog computer which reduces the design of control systems to "knob twiddling" has been completed for Massachusetts Institute of Technology by the Laboratory for Electronics, Inc., Boston. Voltage-dividing resistors represent the coefficients of an equation or the parameters of a system. The operator adjusts these VDR's until the response of the system is optimal and arrives at his answers by multiplying the dial readings with a proper

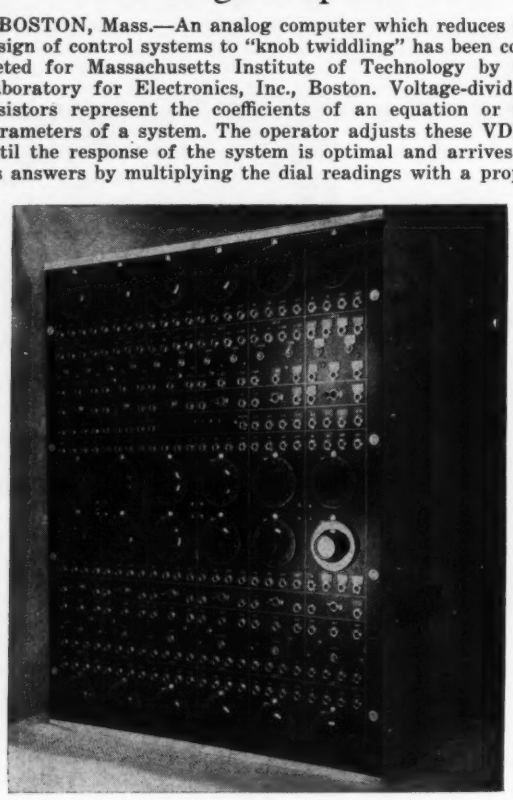


Fig. 1. Analog computer.

scale factor. Using this device, there is no need to solve for roots of characteristic equations of high order. The computer being a dynamic device, analogous to the real system, its performance (including periods of oscillation) is identical to that of the real system. The new computer is an analog for any physical system representable by a linear ordinary differential equation with constant coefficients.

To operate the device, an equation which represents some physical system is first set up in the form of a block diagram. By means of patch cords, the circuits are interconnected to create a circuit similar to the equation. As an example, assume the equation

$$\frac{d^2y}{dt^2} + a\frac{dy}{dt} + by = E$$

This equation, when set up in a block diagram, assumes the form shown in Fig. 2. The circuit becomes two integrators in cascade, an adder stage, and a completed feedback loop. The two coefficients, a and b, are represented by voltage-dividing resistors connected as shown in the diagram. An example of the kind of solution possible is shown in Fig. 3.

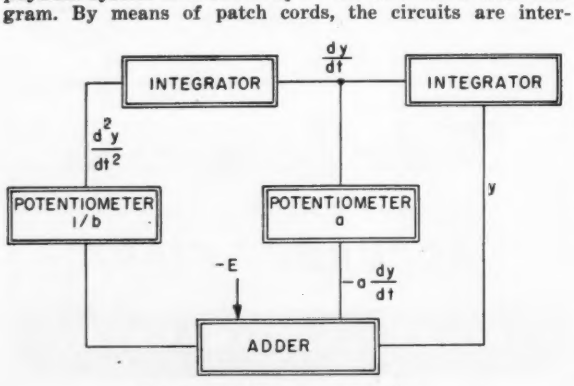


Fig. 2. Block diagram of operation.

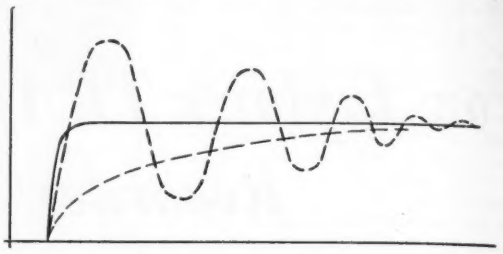


Fig. 3. Types of solutions.

The solid line curve shows conditions which might exist for some settings of the system parameters. Adjustment of the controls enables the operator to try different values of control parameters until the ideal curve is approached as closely as possible.

The unit of the computer in which the equations are set up is called the "Simulator" because it simulates actual physical relationships in a control system. This unit solves linear differential equations up to the 6th degree. The unit consists of 6 channels, each of which contains an integrator and an adder. The use of two "Simulators" makes possible the solution of equations up to the 12th order.

A nonlinear unit is also a part of the system. The unit contains dead-zone and limiter analogs that make it possible to represent imperfections in a practical control system to examine their effect on system performance.

This analog computer is not a commercial product.

New Techniques in Microscopy

CAMDEN, N. J.—Advances in medical research made possible by new uses of both light and electron microscopy were demonstrated by the Radio Corporation of America at the annual convention of the American Medical Association in Atlantic City, June 11 to 15.

The table-model permanent-magnet electron microscope was demonstrated to convention delegates at the society's scientific exhibit in the Municipal Auditorium, the company announced. Principles of operation and of specimen preparation were highlighted.

One hundred of the nation's leading microscopists were invited by RCA to exhibit electron micrographs of viruses, bacterial pathogens, and cytological sections, thus offering visual evidence of the research accomplishments of medical science employing the electron microscope. Included were recent micrographs taken with the instrument in the course of research on polio, cancer, leukemia, and cell and sperm development.

Also demonstrated was the use of television in conjunction with conventional light and ultraviolet microscopes to enable scientists to obeserve vital processes in living cells without staining the specimens. This method, which has been used in the past to bring out detail, often was fatal to the specimens under observation.

For this demonstration, a light microscope equipped with a binocular viewer is used with two TV cameras so that two different color-selective tubes can scan the microscopic scene simultaneously. This provides on two television screens separate images of exceptionally sharp contrast, one showing the blue absorption and the other showing red absorption, at magnifications of 3,000 times.

Electronic Robots

WALTHAM, Mass.—Scientists of the Raytheon Manufacturing Company, at its annual sales convention, stressed the importance to national security of electronic aids to industry, and predicted that electronic robots with superhuman intellects will gradually take over the automatic control of more and more of America's industrial processes during the next 20 years.

They revealed the development of an electronic "memory" device which stores information 1000 times faster and provides a storage capacity 400 times greater than any mechanical card-filing system in use today. Although the electronic memory equipment was developed for the Armed Forces, its functions are applicable to the automatic control of a wide variety of peacetime industrial processes.

Portable Abrasion Tester

WASHINGTON, D. C.—A portable device for testing the abrasion resistance of floor surfaces has recently been developed at the National Bureau of Standards, according to Technical Report 1482. Floor tiles exposed to severe traffic must have approximately the same abrasion resistance; otherwise the floor surface becomes uneven with time. The device tests floor tiles and also is proving useful in the development of better purchase specifications for natural corundum. Corundum grains rather than abrasive wheel is utilized in the tester.

The instrument (Fig. 1) consists essentially of a notched steel wheel (A) mounted on an overhanging frame so that a definite and constant weight bears upon the specimen as the wheel is turned. The tester provides a steady flow of No. 60 artificial corundum betweeen the steel wheel and

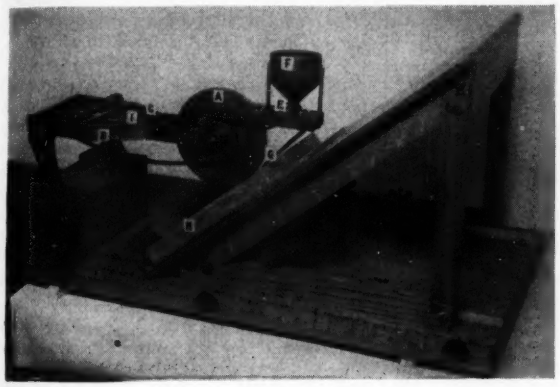


Fig. 1.

the specimen, which is mounted on an incline. The steady flow of abrasive grain accounts for the dependability of the method. In making a test the steel wheel is turned twenty-five revolutions (in approximately one minute), thus cutting a circular segment in the specimen (H). The length of this segment is measured to a tenth of a millimeter and the segment area computed; this value indicates the abrasive resistance of the material. Results obtained with the tester are in good agreement with those provided by the conventional NBS laboratory apparatus.

The instrument has been used in selecting floor tiles for several buildings.

It also is possible with the tester to determine the abrasive quality and break-down characteristics of the corundum. As the grains of an abrasive break into smaller particles during use, the grinding rate is reduced. Thus, by repeating the test ten times with the same portion of sample, a measure of the break-down rate can be obtained. Corundum is used for various purposes, including the grinding of lenses and snagging of wheels. Artificial corundum is superior in abrading value and can be obtained in uniformly high purity. However there seems to be a distinct advantage in natural corundum for lens grinding because of the way the particles break up.

Supplementing the work at the National Bureau of Standards, the U. S. Bureau of Mines has devised a means of analyzing corundum for impurities. Solution of the impurities, floatation, and microscopic determinations are employed. These methods, together with requirements for abrasive values and breakdown rates as worked out by the National Bureau of Standards, have been incorporated in a new specification for corundum.

Scintillation Counter Operates in One Billionth of a Second

PALO ALTO, Calif.—Physicists at Stanford University have developed a technique for counting atomic particles in a billionth of a second. The new technique is for use with the electron linear accelerator, Stanford's new type atom smasher. It will also be applicable to other machines, such as betatrons and cyclotrons, which accelerate particles in pulses. The project, financed by the Office of Naval Research, represents a refinement in development of scintillation counters.

As in other scintillations counters, a photomultiplier tube is used to pick up the minute flashes caused by particles striking scintillation material. The scintillations make an electric signal, which can be measured through oscillographs recordings to determine the count of particles at a given moment. The phototube is a commercial type, but the infinitesimal time it is in operation permits it to be operated at 4000 volts instead of the normal 1000 volts.

Scintillation counters use either crystals or liquids as scintillation material. One of the crystals in common use is transstilbene, chemical relative of stilbesterol, synthetic female hormone. A benzene, with certain chemicals added, is also used.

Hundreds of investigators have been working on applications of the scintillation-counter technique to nuclear, elementary particle, and X-ray physics; to cancer research and diagnosis; and to military and industrial survey instruments. Now, with measurements possible at a billionth of a second, scientists hope that they may be able to step up the speed even faster so that it will be possible to make accurate "time of flight" measurements—to know how long it takes a particle to go from one given point to another. One of the reasons this is important is that if scientists know the energy and speed of a particle, they can determine its mass. Other determinations of the mass of particles have been by inference, and this would be an additional and direct method of determining an important factor in the study of atomic particles.

GORDON RESEARCH CONFERENCES, AAAS

Program of Conference on Instrumentation, Colby Junior College, New London, N. H., July 30-August 3, 1951.

Monday, July 30.—Van Zandt Williams, Recent Advances in Infrared Instrumentation. R. C. Mellors, Microspectrophotometry. Bruce Billings, Interference Filter Spectroscopy.

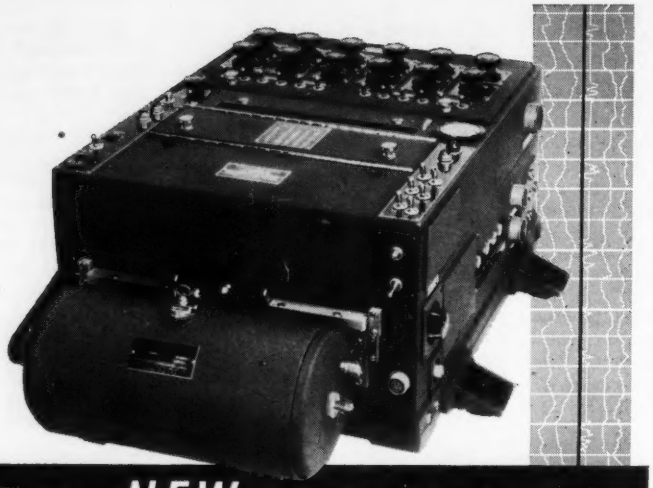
Tuesday, July 31.—J. W. Forrest, Refractometry. John Strong, Instrument Art and Experimental Science. G. W. Downs, Magnetic Amplifiers.

Wednesday, Aug. 1.—P. W. Selwood, Magnetic Measurements in Physical Chemistry. W. A. Wildhack, Instrumentation Research at the Bureau of Standards. E. C. Miller, Process Control Instrumentation.

Thursday, Aug. 2.—John Hipple, Mass Spectrometry of Solids. Speaker to be announced, Automatic Mass Spectrometer Process Control. Speaker to be announced, Mass Spectrometer for Aqueous Samples.

Friday, Aug. 3.—Speaker to be announced, Microwave Refractometry. Speaker to be announced, Neutron Spectroscopy.

Applications should be addressed to Conference Director W. George Parks, Colby Junior College, New London, New Hampshire.



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ORIFICE-METER MEASUREMENTS

(*Continued from page* 765)

reasonably constant, the average value may be used:

TOTAL DELIVERED =

$$\int_0^{24} Q\,(\text{meas.})\,dt - E_{RO}\,(\text{av.}) \int_0^{24} Q\,(\text{meas.})\,dt.$$

From the analysis thus far, we may draw certain conclusions which relate to the method rather than to the means of instrumentation:

(1) Of the possible variables which can be inferentially determined and related to pulsation error, the dimensionless ratio "R" (the rms. component of fluctuating differential pressure divided by the average differential pressure) appears to be the best choice. This is because the function $E_{RO}=f(R)$ is independent of frequency and only slightly influenced by waveform for erors of less than 7 percent.

(2) The method allows for the shape of the waveform in the determination of R. The waveform may be simple or complex and may vary at random without appreciably affecting the accuracy of the method.

(3) When the averaging process for determining $h_{rms.}$ involves a long averaging time-constant, R reveals the true overall effect of varying amplitude fluctuations. Such fluctuations might cause completely misleading information to be obtained from a device which only measures pressure peaks.

(4) It should be possible by obtaining sufficient field-test data to arrive at plotted curves for $E_{RO}=f(R)$ which, for certain types of compressor and metering installations, would give the pulsation correction to within 1 percent for errors up to 10 percent or more.

Required Instrumentation

Indicating Instrument.—For installations where the flow conditions remain reasonably constant for several hours at a time, or where the chief purpose is merely to make periodic checks on the pulsation conditions, an indicating instrument is the simplest solution. The indicating instrument may be one of several forms. One practical form is indicated in Fig. 1.

The transducer is a strain-gage type differential-pressure transducer excited by direct current from the power source. The frequency response of the transducer is flat from 0 to 200 cps. This transducer produces a signal proportional to instantaneous pressure, which is fed through a capacitator (to eliminate the d-c. component of the pressure signal). The signal then is amplified in the a-c. amplifier, which supplies current to a thermomilliammeter. The thermomilliammeter thermocouple element responds to the true rms. value of the current, hence the scale is calibrated directly in rms. inches of water. Current feedback is employed to reduce the effects of varying tube characteristics and supply voltage. The feedback

resistor is selected of the proper materials to compensate for the slight effects of ambient temperature on the thermomilliammeter.

In use, the value of $h_{rms.}$ found from the instrument is divided by $h_{av.}$ measured by the flowmeter to obtain R. E_{RO} then is obtained from Fig. 3 as explained previously.

Recording instruments.—For installations where large pulsations are present and where flow conditions change markedly during the day, a recording instrument is desirable. One type of recording instrument might record the pulsations in terms of $h_{rms.}$. A more complex type of instrument might make use of both the fluctuating and average components of pressure measured by the transducer and record E_{RO} on a 24-hour chart. Such instruments would be considerably more expensive than the indicating instruments. The recording type of instrument is still in the initial phase of development.

The installation of the transducer should be made in such a way that the distance from the transducer element to the pressure taps is as short as possible. This eliminates the possibility of resonance in the lines. If the lines from the flowmeter to the pressure taps are long, the transducer should be mounted near the orifice and not near the flowmeter The usual precautions regarding equal line volumes and equal entrance and discharge coefficients should be observed in the flowmeter installation to insure that the meter responds to the average differential pressure across the orifice.

Conclusions

In conclusion, it is believed that the methods and form of instrumentation described are a practical answer to the measurement of pulsating flow. The pressure transducers and electronic equipment required can be made to give reliable results. Unfortunately, the required transducers and other specialized components are expensive. However, it should be possible to amortize the cost of the equipment within a few months on gas transmission lines.

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Plan to attend!

Sixth Instrument Conference and Exhibit

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See page 759

SANBORN

1, 2 and 4 channel

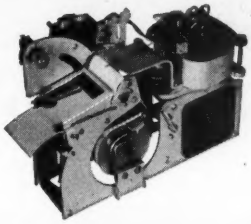
RECORDING SYSTEMS

DIRECT WRITING · NO INK

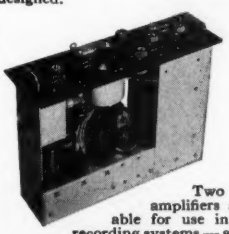
RECTANGULAR COORDINATES

PERMANENT RECORDS

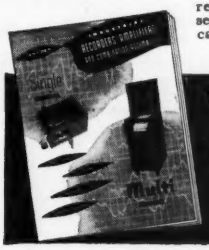
RECORDERS AND AMPLIFIERS AVAILABLE SEPARATELY



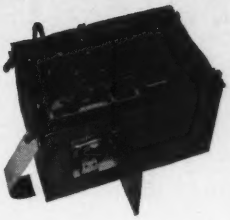
In all Sanborn recorders, tracings are produced by a heated writing stylus in contact with heat sensitive, plastic-coated paper. The paper is pulled over a sharp edge in the paper drive mechanism, and the stylus wipes along this edge as it swings; thus producing records in true rectangular coordinates. The writing arm is driven by a D'Arsonval moving coil galvanometer with extremely high torque movement (200,000 dyne cm/cm deflection). Standard paper speed for the Model 51-600 recorder assembly, shown above, is 25 mm/sec. Slower speeds are available. Paper width 6 cm with 5 cm recording area. The assembly shown above is used in Models 128 and 141 (described above right) and provides the basic principles and methods on which recorders for the 2- and 4-channel systems are designed.



Two types of amplifiers are available for use in Sanborn recording systems — a DC General Purpose Amplifier, and a Strain Gage amplifier (shown above). The amplifiers used in the 2- and 4-channel systems are generally identical with those in the 1-channel system, which are available, as are also all the recorders, for separate application.



1 CHANNEL RECORDING SYSTEMS

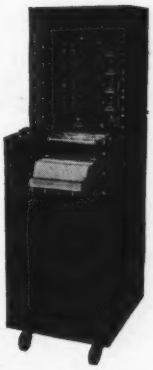


Model 128 comprises a DC General Purpose Amplifier in combination with the Recorder Assembly shown below left, to which is added panel, transformer, and controls. Both instruments are contained in a single hardwood carrying case. The complete system is a vacuum tube recording voltmeter capable of reproducing in rectangular coordinates any electrical phenomena from the order of a few millivolts to more than 200 volts. When a Strain Gage Amplifier is specified, the system becomes Model 141. Amplifiers are readily interchangeable. When a built-in timer is included for either, the Model numbers become 128T or 141T.

2 CHANNEL RECORDING SYSTEMS

The two channels of **Model 60** operate independently of each other, but record simultaneously. Ten paper speeds are standard equipment, in pairs of: 5 and 0.5, 10 and 1, 25 and 2.5, 50 and 5, 100 and 10 mm/sec. Ready interchangeability of amplifiers (DC and Strain Gage) and preamplifiers (DC and AC) makes possible the availability of a variety of input circuits. Timing and coding are built-in features. Each channel has a 5 cm recording width.

4 CHANNEL RECORDING SYSTEMS



Model 67 provides for the direct, simultaneous registration of up to four phenomena on one record, using the same principles and methods as the two systems described above. In addition, there is a selection of eight paper speeds: 50, 25, 10, 5, 2.5, 1.0, 0.5, and 0.25 mm/sec., and provision for the use of 4-, 2-, or 1-channel recording Permapaper. As in Model 60, above, amplifiers and preamplifiers are readily interchangeable.

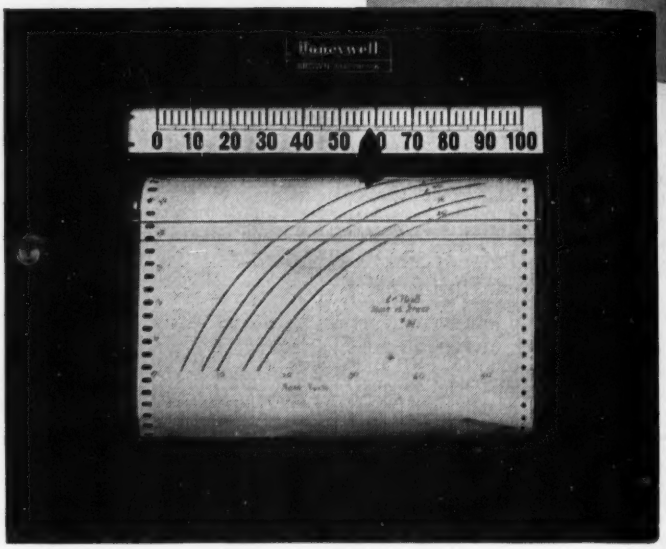
For complete descriptions, illustrations, tables of constants, and prices, write for catalog.

INDUSTRIAL DIVISION

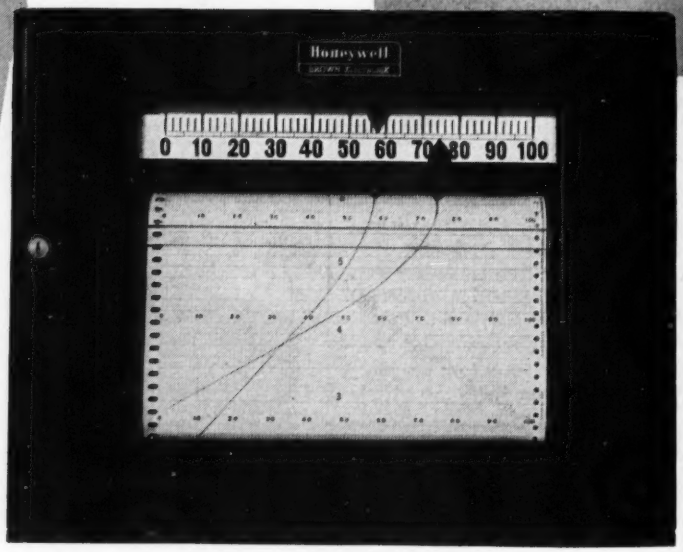
Sanborn Company

CAMBRIDGE 39, MASSACHUSETTS

THESE NEW INSTRUMENTS SHOW VARIABLE COMPARISONS AT A GLANCE



FUNCTION PLOTTER
Send for Data Sheet 10.0-5



DUPLEX RECORDER
Send for Data Sheet 10.0-6

The *ElectroniK* Function Plotter

Records a Precise and Continuous Curve of $y=f(x)$

Gone are the days of labored hand plotting . . . logging countless readings . . . missing in-between values . . . consuming valuable time. Now you can automatically record a precise and continuous curve representing the relation of any two variables, that can be reduced to a d-c voltage, by connecting them to the new *ElectroniK* Function Plotter. Every point of the curve will be recorded *exactly as it is measured.*

Applicable to countless analyses and investigations, the *ElectroniK* Function Plotter is being used for plotting such curves as speed vs. torque, stress vs. strain, temperature vs. pressure, volume vs. pressure, force vs. displacement, hysteresis loops, etc.

The *ElectroniK* Duplex Recorder

Simultaneously Plots Totally Independent Variables on One Chart

The possibilities of this instrument are practically limitless. You can make a before-and-after comparison of a measurable property as it enters and emerges from a processing stage or reaction . . . you can continuously measure practically any two variables on the same chart—compare and study these variables without effort, save valuable time and eliminate possibility of error in cross reference.

The instrument permits any two variables to be recorded as a function of time. By using a Selsyn motor, it can be used to record two independently measured variables as a function of motion or displacement. Since the two measuring circuits are entirely separate, actuations and ranges are supplied to suit the requirements of the application.

MINNEAPOLIS-HONEYWELL REGULATOR Co., *Industrial Division*, 4482 Wayne Ave., Philadelphia 44, Pa.

MINNEAPOLIS
Honeywell
Brown Instruments

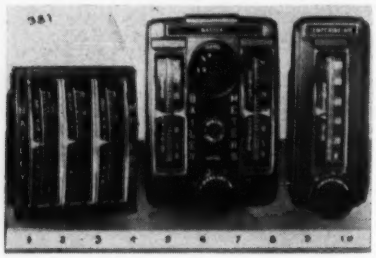
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, computing, metering and automatic control—in the form of concise technical descriptions.

FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 825

Miniature Indicators and Control Units

New "Mini-Line" miniature indicators and control units include all information and controls for operating



boilers, turbines, and process units. Panels will be more than 50 percent smaller. New units include multi-point indicator, selector valve, and remote manual relay.—*Bailey Meter Co.*, 1050 *Ivanhoe Road, Cleveland* 10, *Ohio.*

Mention No. 701 when filling out card.

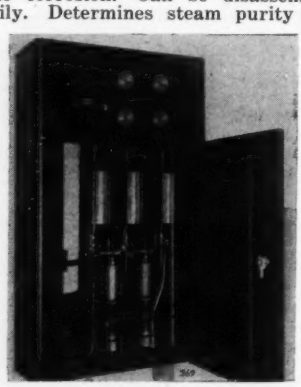
Electrical Analog Computer

New "Vapor-liquid Equilibrium Computer" has seven computing units, which comprise resistance networks, servomechanisms, and outputs proportional to mol-fractions for vapor and liquid phases. Designed by Phillips Petroleum Co.; maker: *Devico Corp.*, 901 *Greeley Ave., Webster Groves* 19, *Mo.*

Mention No. 702 when filling out card.

Automatic Degasser

New model of "Automatic Degasser" has case of mild steel treated to minimize corrosion. Can be disassembled easily. Determines steam purity and



produces continuously and automatically an approximate 50-50 split of flowing steam sample. One fraction contains dissolved solids and other dissolved gases that may be present.—*Hagan Corporation, Hagan Bldg., Pittsburgh* 22, *Pa.*

Mention No. 703 when filling out card.

Portable Pyrometer

New "Type LT-840 Xactemp" is self-contained high-resistance millivoltmeter pyrometer for rapid temperature determination below 800 F. Choice of four

calibrations. Available for use are two needle thermocouples, a ribbon thermocouple, a surface tip thermocouple, and other thermocouples and extension arms.—*Claud S. Gordon Co.*, 3000 *S. Wallace St., Chicago* 20, *Ill.*

Mention No. 704 when filling out card.

Immersion Thermocouple Pyrometer

New thermocouple pyrometer for open hearths or electric furnaces consists of platinum vs. platinum+10-percent rhodium immersion couple and

"Speedomax" pyrometer with signaling features. Heating of tube during immersion does not cause cold-junction error. Recorder operates three signal lights. Green light stays on as long as thermocouple circuit is closed. Amber light comes on when recorder pen moves upscale, shows that couple is in operating condition. Red indicates when couple registers bath temperature; tells operator when to withdraw couple. "Speedomax" range is 2400 to 3200 F. Recorder automatically standardizes potentiometer circuit.—*Leeds & Northrup Co.*, 4934 *Stenton Ave., Philadelphia* 44, *Pa.*

Mention No. 705 when filling out card.

Air-fuel Ratio Controller

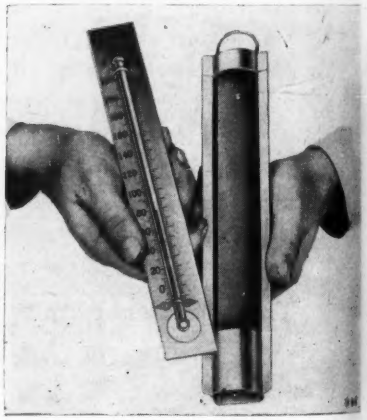
New air-fuel ratio controller adjusts air flow to fuel flow changes rapidly without cycling. Available for use where ratio control alone is desired.

Models supplied to operate electric or pneumatic control valve. Wide range of proportional-band and reset control actions. Ratio range from 50 percent deficiency to 100 percent excess air.—*Leeds & Northrup Co.*, 4934 *Stenton Ave., Philadelphia* 44, *Pa.*

Mention No. 706 when filling out card.

Steel-case Thermometer

New "TAG Model 8689" thermometer incorporates heavy corrosion-resistant stainless-sheet-steel case, welded throughout. Can be obtained in five ranges from –40 F. to 400 F. Removable scale and tube unit for easy replacement. Scale piece buttresses sides

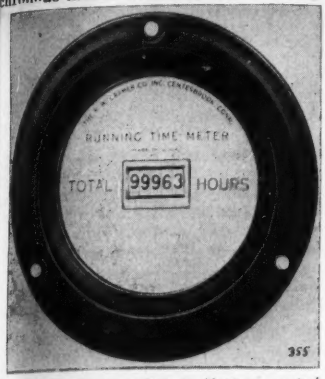


of case, so that no torque can be transmitted to scale to shift calibration on snap tube.—*Tagliabue Instruments Div., Weston Electrical Instrument Corp.*, 614 *Frelinghuysen Ave., Newark* 5, *N. J.*

Mention No. 707 when filling out card.

Running-time Meter

New hermetically-sealed running-time meter consists of self-starting synchronous motor which operates a regis-



ter through a gear train. Registers total operating time or idle time. A-c. operated.—*R. W. Cramer Co., Inc., Centerbrook, Conn.*

Mention No. 708 when filling out card.

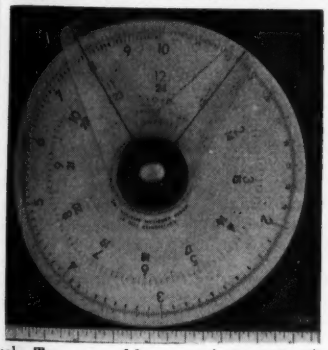
Sampling Monitor for Production-quality Control

New "continuous sampling monitor" is electrical device which automatically keeps track of sampling procedure and eliminates paperwork inherent in continuous sampling methods of quality control. Electric counter automatically keeps track of clearance number. When counter reaches set number, white sampling light indicates that a predetermined number of acceptable units has been inspected, and that sampling can resume. Percentage inspection or sampling may vary from 1 to 50 percent depending on the desired AOQL. Maximum counting speed is 500 units per minute.—*Special Products Div., General Electric Co., Schenectady 5, N. Y.*

Mention No. 709 when filling out card.

Time-study Computer

New "Time and Production Cost Computer" is a plastic 4-in. circular disk upon which is a time scale and log

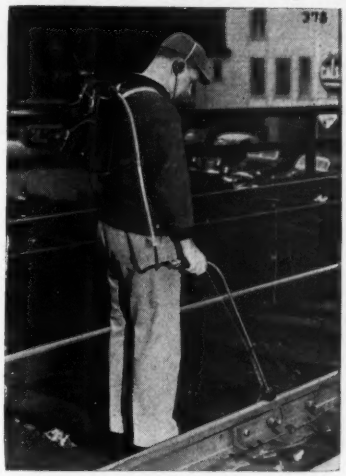


scale. Two movable arms integrate time clock in terms of man hours, unit or aggregate product cost, job efficiency, and relative proportions.—*Willer Sales Co., P. O. Box 10008, International Airport, Los Angeles 45, Calif.*

Mention No. 710 when filling out card.

Ultrasonic Flaw Detector

New "Audigage" flaw detector detects hidden defects. Ultrasonic resonance generates tone in headphones.

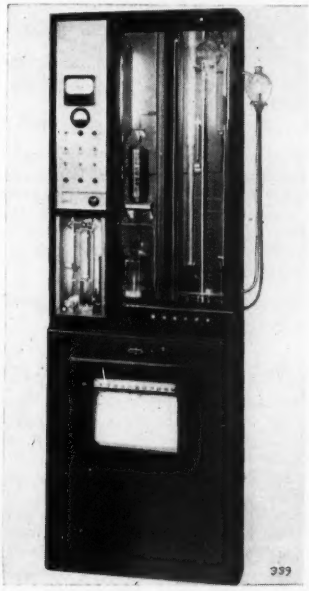


Flaw revealed by pitch of signal. X-cut quartz-crystal transducer is swivel-mounted. Weighs twelve pounds. Power supplied by batteries.—*Branson Instruments, Inc., 430 Fairfield Ave., Stamford, Conn.*

Mention No. 711 when filling out card.

Adsorption Fractionator

New adsorption fractionation apparatus provides analysis of light hydrocarbon gases including pentanes. Gases are separated, identified and measured

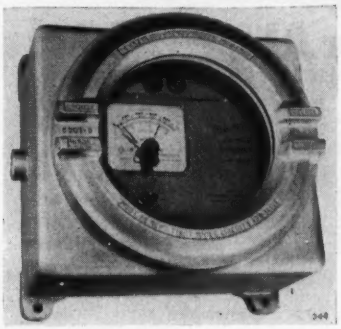


by volume of separated fractions. Separation is by physical adsorption. Identification is by measurement of thermal conductivities. Volume of each fraction is by determining change in pressure of evacuated system. Accuracies of 0.2 percent. Records made on potentiometer.—*Burrell Corp., 2223 Fifth Ave., Pittsburgh 19, Pa.*

Mention No. 712 when filling out card.

Explosion-proof Pyrometer Controller

New explosion-proof pyrometer controller consists of "Panelmount Simplytrol Style 11 Control" mounted in stand-

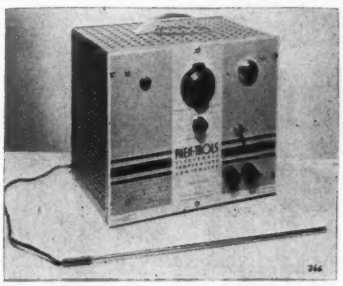


ard Crouse-Hinds explosion-proof "Type GUB Instrument Conduit."—*Assembly Products, Inc., Main at Bell St., Chagrin Falls, Ohio*

Mention No. 713 when filling out card.

Temperature Controller

New temperature controller is direct dial-setting type and maintains preselected temperature within 0.50 C. Operates from 115-volt 60-cycle current.

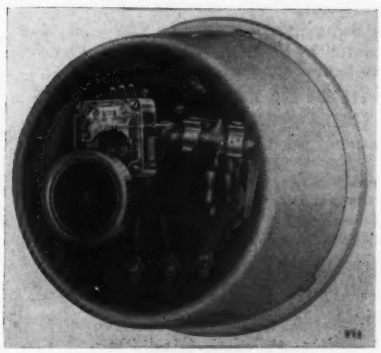


Handles loads up to 3,000 watt capacity. Equipped with plug-in receptacles for hook up of devices or to solenoid or other temperature controls. Stainless-steel thermocouple actuates unit. A similar model available for temperatures below O C.—*Phen-Trols, Inc., 15 Franklin Place, Rutherford, N. J.*

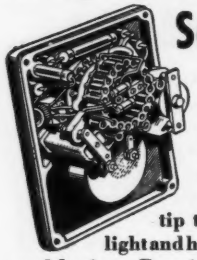
Mention No. 714 when filling out card.

Illumination Controller

New "Model 1809" weatherproof plug-in unit provides "on-off" control of artificial lighting at predetermined light levels. Consists of dry-disk pho-



Adjust Heat INSTANTLY for ALL TYPES of Soldering



Controlled dual heat—on in 5 seconds, off when you release trigger—lets you adjust tip temperature for light and heavy instrument soldering. Precision balance, longer reach and tip construction ideal for delicate jobs. Rating up to 250 watts speeds heavy work. Time-and-power savings pay for your Weller Gun in a few months.

250-Watt WELLER SOLDERING GUN for Light *and* Heavy Instrument Work

- **TRIGGER-SWITCH CONTROL**—Ideal for intermittent work. No need to unplug gun between jobs.
- **5-SECOND HEATING**—No waiting, no wasted current.
- **PRECISION BALANCE**—Simplifies delicate work.
- **SOLDERLITE**—Spotlights the work.
- **LONGER REACH**—Slides easily into tight spots.
- **WELLERTIP**—Chisel shaped for faster heat transfer. Over/under terminals brace tip for heavy duty.
- **DUAL HEAT**—Single heat 200 watts; dual heat 200/250 watts; 120 volts, 60 cycles. For all instrument soldering.

See the 250-watt Weller Soldering Gun at your distributor, or write for bulletin direct.

SOLDERING GUIDE—Get your new copy of "Soldering Tips"—revised, up-to-date, fully illustrated 20-page booklet of practical soldering suggestions. Price 10c at your distributor, or order direct.

WELLER ELECTRIC CORP.
800 Packer Street, Easton, Pa.

NEW INSTRUMENTS

tocell, relay operated by photocell, clock motor, mercury switch and limit switch. Plugs into standard watthour meter receptacle. Functions from 140 F. to –30 F.—*Weston Electrical Instrument Corp.*, 641 *Frelinghuysen Ave., Newark* 5, *N. J.*

Mention No. 715 when filling out card.

Spotweld Control

New "slope-control" system extends electrode life 20-30 times when spot-welding aluminum. System restricts flow of welding current during first few cycles, allowing welding current to build up gradually to maximum. Gradual softening of metal under electrode tip helps maintain tip pressures and holds down tip temperatures, thus reducing "sticking."—*Reynolds Metals Co.*, 2500 *South Third St., Louisville* 1, *Ky.*

Mention No. 716 when filling out card.

Peak-pressure Indicator

New "Model PPM-1" peak-pressure meter indicates peak value of short-duration voltage pulse such as that generated by a piezoelectric pressure

pickup. It is portable and non-microphonic. Peak voltage can be read to accuracy of 1 percent for 2 minutes after occurrence. Required minimum duration of input signal, 0.02 millisecond.—*Shepard Laboratories*, 430 *Morris Ave., Summit, N. J.*

Mention No. 717 when filling out card.

Production Control Boards

New features for "Visi-Trol" boards include: steel channels in several widths; plastic letters, figures and strips; moldings and accessories. Channels can be assembled vertically, horizontally, or diagonally or any combination thereof. Flame-resistant letters snap in or out of channels. Telescopic strips speed chart changes.—*Visi-Trol Corp.*, 21460 *W. Eight Mile Road, Detroit* 19, *Mich.*

Mention No. 718 when filling out card.

Moisture Meter

New "Model 919" moisture meter is battery-operated and portable. Electronic circuit consists of two tubes, a standard for calibration purposes, and a ball-bearing-mounted precision variable capacitor on which is mounted

scale drum. Circuit is compensated for temperature variations. Small power supply is available. Temperature range: –20 F. to 110 F.; relative humidity up to 95 percent. Electronic balance for weighing grain prior to measurement is extra.—*Halross Instruments Corp. Ltd.*, 171 *Garry St., Winnipeg, Manitoba, Canada.*

Mention No. 719 when filling out card.

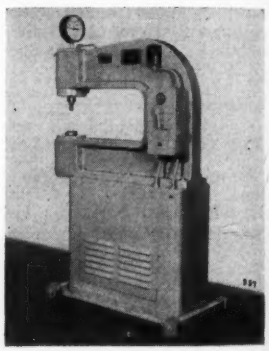
Starter-controller

New "Combination Life-Linestarter (Class 11-206-NJ)" for starting and controlling heavy equipment is available in NEMA sizes 1 through 5, with ratings up to 200 hp., 400 volts polyphase. Has overload relays. Starters are furnished as standard with 220/440-volt primary, 110-volt fused secondary, control-circuit transformer that can be used on either 220- or 440-volt supply voltage, 50 or 60 cycles.—*Westinghouse Electric Corp., Box* 2099, *Pittsburgh* 30, *Pa.*

Mention No. 720 when filling out card.

Hardness Tester

New "Model AP-1" Brinell hardness testing machine has throat depth of 24 in. and is mounted on wheels. Lower anvil is top of hydraulic piston, which



rises as load is applied to take pressure off conveyor. Maximum vertical opening between ball penetrator and anvil is 4 in. Weight is 900 lbs.—*Steel City Testing Machines, Inc.*, 8843 *Livernois, Detroit* 4, *Mich.*

Mention No. 721 when filling out card.

Planetarium Projector

New improved model of Carl Zeiss Planetarium Projector is again available on order. In all, 26 Zeiss projectors have been built. Twenty are in Europe and six in United States. Projector shows 9,000 stars plus the sun, moon, and planets on a huge dome. All can be shown in their correct position for any

instant, year, or century, and as seen from any viewpoint on earth. The motions are controlled by seven motors.—*Ercona Corp.*, 527 *Fifth Ave., New York* 17, *N. Y.*

Mention No. 722 when filling out card.

Displacement Indicator and Controller

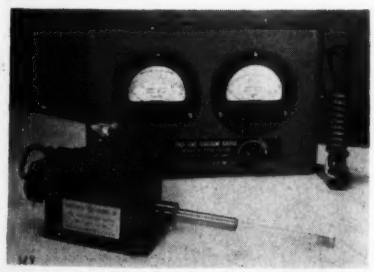
New "Type 131 Electronic Displacement Indicator and Controller" is for use in conjunction with "Schaevitz Linear Variable Differential Transfor-

mers" and "Schaevitz Pressure Transmitters." Range of displacement control is ±.001 to ±1.000 in. Greater displacements can be handled by mechanical leverage. Pressure control is available in range from 0 to 10,000 psi. Accuracy of the instrument is ±2 percent.—*Sterling Instruments Co.*, 13331 *Linwood Ave., Detroit* 6, *Mich.*

Mention No. 723 when filling out card.

Vacuum Gage

New "Model 6" of maker's "Tru Vac" utilizes hot-wire principle; has dual ranges (0.5 to 500 and 500-3000 microns); is available in four models for use on soft-glass, hard-glass, metal



and vacuum-hose systems. Gage operates on 6-v. d.c. and is provided with a milliammeter for current regulation. —*Continental Electric Co., Geneva, Illinois.*

Mention No. 724 when filling out card.

Electric Printer

New electric indicator and printer, intended primarily for use with low-resistance strain-gage devices, prints full block figure on card or tape. 60-cycle system eliminates standard cells and totalizes 2 to 4 input signals. Input

NEW *Berkeley* DECIMAL SCALERS!

GM OR SCINTILLATION COUNTING*

SINGLE "H.V." CONTROL

SMALL — LIGHTWEIGHT

POSITIVE OR NEGATIVE "H.V." SUPPLY*

ELECTRONIC SCALE-OF-100

DIRECT READING

PREDETERMINED COUNT*

LOW COST

MODEL 100

***Berkeley* Basic Scaler**

SINGLE HI-VOLTAGE CONTROL simplifies operation, prevents inadvertent over voltaging of GM tubes. Single continuous control from 0 to 2,500 volts.

TRUE DECIMAL PRESENTATION for easy reading. No interpolation, no lights to add. Results are presented in direct reading form on illuminated panels of the two electronic counting units. A 6-place mechanical register extends total capacity to 99,999,999. Selectable electronic scale of 10 or 100.

SMALL, LIGHTWEIGHT for easy portability. Weighs only 18 lbs.; measures 9¾" x 10¾" x 14½". Baked enamel finish permits easy decontamination.

ACCESSORY OUTLETS are provided for external clock, timer, loudspeaker, or output pulse per count to drive count rate meter or counting rate computer and recorder.

***MODEL 110**

***Berkeley* Universal Scaler**

This versatile scaler has all the features of the Model 100, plus:

POSITIVE OR NEGATIVE HI-VOLTAGE SUPPLY, selectable by simple internal switch, permits use with either GM or scintillation detectors.

BUILT-IN PREDETERMINED COUNTER provides presettable scaling factors of 100, 200, 400, 1,000, 2,000, 4,000, 10,000 and 20,000.

LOW COST:

The Model 100, produced in quantity, provides a basic Geiger-Muller Scaler at minimum cost. **Price $330**

The Model 110, with its added features, offers maximum flexibility in meeting your every counting need. **Price $425**

For complete information, write for bulletin 100-I

Berkeley Scientific Corporation

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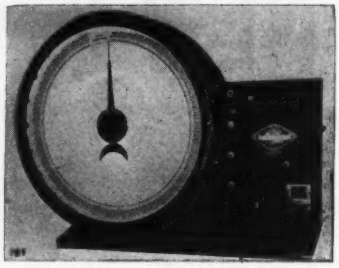
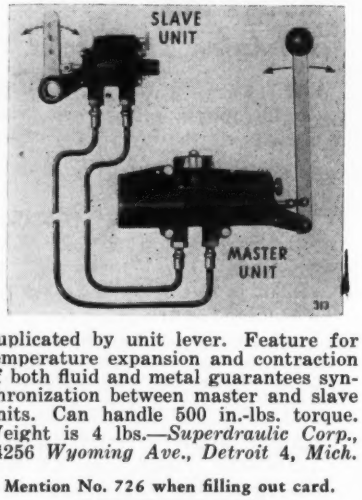


signal is indicated on 20-in. dial and recorded on card or tape by pushbutton. Accuracy is 0.1 percent of capacity for printer and 0.2 percent of capacity depending on type of cell used. Speed is full scale in 6 seconds—12 or 24 seconds for oscillating loads or measurements.—*Gilmore Technical Associates*, 5511 *Euclid Ave., Cleveland* 3, *Ohio.*

Mention No. 725 when filling out card.

Hydraulic Remote Control

New "Superdraulic" control system consists of master unit and slave unit interconnected by two small tubes. Motion applied to lever of master unit is

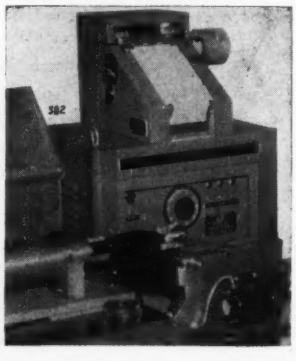


duplicated by unit lever. Feature for temperature expansion and contraction of both fluid and metal guarantees synchronization between master and slave units. Can handle 500 in.-lbs. torque. Weight is 4 lbs.—*Superdraulic Corp.*, 14256 *Wyoming Ave., Detroit* 4, *Mich.*

Mention No. 726 when filling out card.

Crack Detector

New "A.C.D.T." detects and records crack-shaped flaws in ferromagnetic tubular products. Inspection head travels through bore of tubes. Facsimile

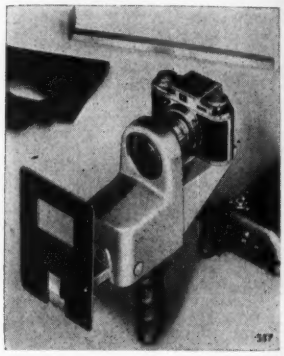


paper chart moves at rate proportional to travel of head through bore. Sensitivity is adjustable to eliminate negligible flaws on record. Speed of testing depends on minimum size of flaw to be detected. A 1-in. crack shows up at 15 linear ft. per min.—*Graydon Smith Products Corp.*, 150 *Causeway St., Boston* 14, *Mass.*

Mention No. 727 when filling out card.

Research Camera

New camera comprises a 35-mm. close-up camera, built-in strobo light, and system of "range frames." Strobo light source is ring-shaped tube concentric with camera lens. Frames cover-

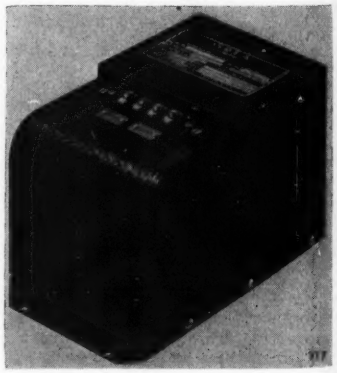


ing various areas are used as guides in setting camera and shooting. Camera features an f:3.2 44-mm. hard-coated, color-corrected lens with coupled rangefinder, speeds of 1/10th, 1/100th, 1/200th sec., time, and bulb.—*Bolsey Corp. of America*, 118 *East* 25*th St., New York* 10, *N. Y.*

Mention No. 728 when filling out card.

Electrical Control System

New "Sensivolt" controls electrical machinery by reacting to as small as 0.5 v. changes in a-c. line voltage; can be used to react automatically to unpredictable fluctuations in voltage; or



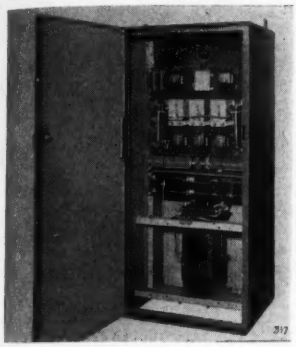
can be stimulated by modulating voltage at power source. Basis: a resonant electric circuit (somewhat similar to constant voltage transformer) consisting of a primary winding, a secondary winding and a relay coil winding in series with a capacitor, which comprise resonant circuit. Magnetic circuit consists of a closed core provided with a magnetic shunt. New system is said to "provide a way for the en-

gineer with a problem of a-c. voltage control which is not dependent on vacuum tubes or delicate relays for the control circuit." Controls can be made for any power system frequency, but it is necessary to have a fixed frequency.—*Sola Electric Co., 4463 W. 16th St., Chicago 50, Ill.*

Mention No. 729 when filling out card.

Electrical Automatic Regulator

New "Regulex" rotating amplificr-type generator-voltage regulator has no moving parts or electron tubes in voltage measuring and control panel. Equipment consists of compensating unit for reactive-current division, stabilizer panel, static voltage-measuring

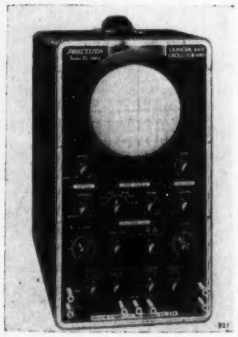


circuit, battery-excitation switch and resistor, and a damping-transformer assembly. Knob on reactive compensating units adjusts autotransformer. Includes motor generator set, manually or motor-operated main exciter-field rheostat, and voltage-adjusting equipment. Used to control synchronous machines, to control voltage, power factor or current, and to prevent over-excitation or under-excitation.—*Allis Chalmers, Milwaukee, Wis.*

Mention No. 730 when filling out card.

Oscilloscope

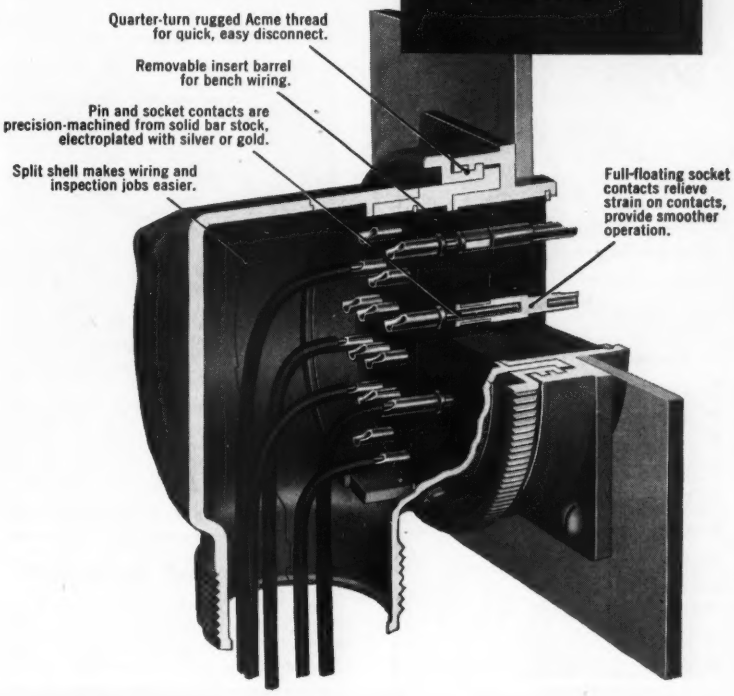
New "Series ES-500A" high-sensitivity cathode-ray oscilloscope has 5-inch tube and push-pull amplifiers with response beyond 1 mc. Input resistance



is 2 megohms, approx. 20 mmfd. input capacity. Vertical amplifier sensitivity is 20 millivolts per in. Calibrated input step-attenuator. Internal linear sweep from 10 cycles to 30 kc. Internal, phasable 60-cycle beam blanking plus Z-axis beam-modulation input terminals for external blanking and timing. Built-in horizontal phasing control. Audio monitoring phone jacks at rear of cabinet

Here's why those in the know –demand

CANNON PLUGS


Quarter-turn rugged Acme thread for quick, easy disconnect.
Removable insert barrel for bench wiring.
Pin and socket contacts are precision-machined from solid bar stock, electroplated with silver or gold.
Split shell makes wiring and inspection jobs easier.
Full-floating socket contacts relieve strain on contacts, provide smoother operation.

Recognition of Cannon's 36 years of sound engineering and fine, uncompromising construction has built the demand for Cannon Plugs. Here we take an inside look at the lightweight Type "K" 90° connector, forerunner of the Army-Navy Series. More features of the "K" were incorporated into the "AN" design than any other connector.

Constantly improved over the years, Type "K" is now used for numerous applications such as aircraft, radio, television, sound, phone recorders, motion pictures, geophysical research and widely used throughout the electro-mechanical and electronic instrument fields.

The design and construction details in the Cannon "K" Series are typical of the care Cannon takes in producing more than 18,000 precision, multi-contact connectors to serve the exacting needs of industry.

We will gladly send you engineering bulletins describing each of the many basic types of Cannon Plugs if you will briefly describe your applications.

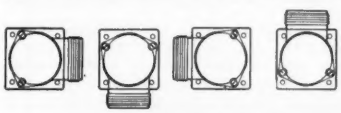


Diagram at left shows how the four positions of cable entry on the large 90° "K" endbell make the wiring job easier. Smaller Type "K" connectors have three positions.

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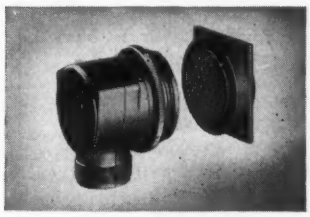

Type "K" and "RK" connectors are available in 7 shell types having 8 diameters. Inserts have more than 190 contact arrangements. Some of these have Coax, Twinax or Thermocouple contacts as standard. Integral cable clamps available in all "K" plug types.

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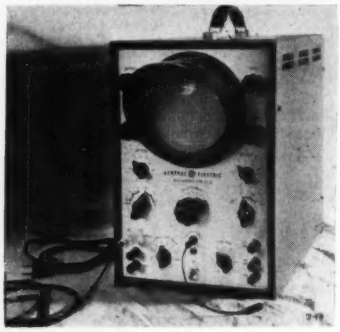
NEW INSTRUMENTS

plus direct access to H and V deflection plates. Employs 13 tubes.—*Precision Apparatus Co., Inc., 92-27 Horace Harding Blvd., Elmhurst, L. I., N. Y.*

Mention No. 731 when filling out card.

Oscilloscope

New "Type ST-2C" 5-in. oscilloscope has vertical sensitivity (a-c. input) of 0.075 volts rms. per inch. Vertical-amplifier frequency response is 20 cps. to

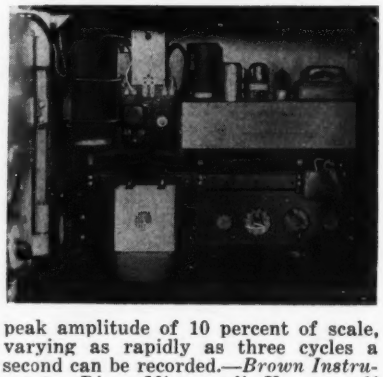


3 Mc. Weight is 43 lbs. Voltage calibrator included can be varied from 0.3 to 300 peak-to-peak volts.—*Commercial Equipment Div., General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 732 when filling out card.

High-speed Recorder

New "ElectroniK" high-speed recorder measures and records variables which vary as rapidly as 20 cycles a minute (full-scale). Variables with peak-to-



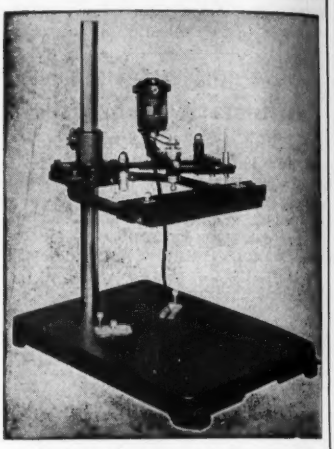
peak amplitude of 10 percent of scale, varying as rapidly as three cycles a second can be recorded.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Philadelphia 44, Pa.*

Mention No. 733 when filling out card.

Carrier-system Auxiliary

New "Type H1-D" dial signal attachment can be added to "H-1" carrier communication systems; provides full-duplex carrier-frequency dial-signaling pulses at 10 to 14 p.p.s. on frequencies not essential to voice channels. Includes stabilized v-t. oscillators for generating signaling frequencies, which are transmitted to the line under control of relays actuated by d-c. signals from the terminal equipment. Incoming pulses are reconverted into d-c. signals to op-

MICO ENGRAVER
Model 253



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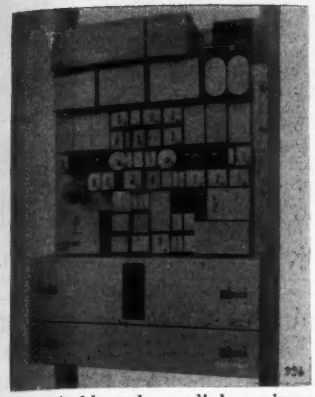
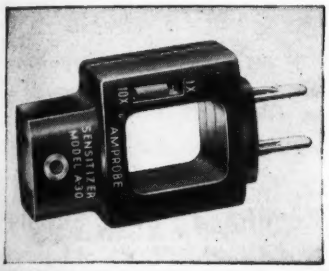


erate switchboard or dial equipment. Operations in two directions of transmission are independent.—*Lenkurt Electric Co., 1105 County Road, San Carlos, Calif.*

Mention No. 734 when filling out card.

Sensitizer for Appliance Tester

New "Dual Purpose Model A-30 Sensitizer" changes sensitivity of maker's "Amprobe" by a factor of 10. This adds three low-current ranges: 0-1, 0-2.5, 0-5

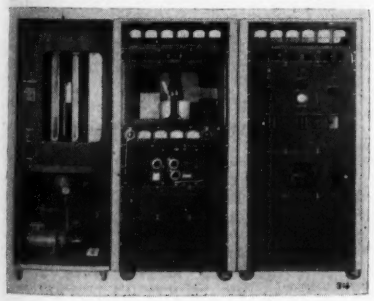


amps. Two-position switch shifts from sensitizer to split plug. Split plug facilitates snap-on current readings of equipment having sealed double-conductor electric cord.—*Pyramid Instrument Corp., 49 Howard St., New York 13, N. Y.*

Mention No. 735 when filling out card.

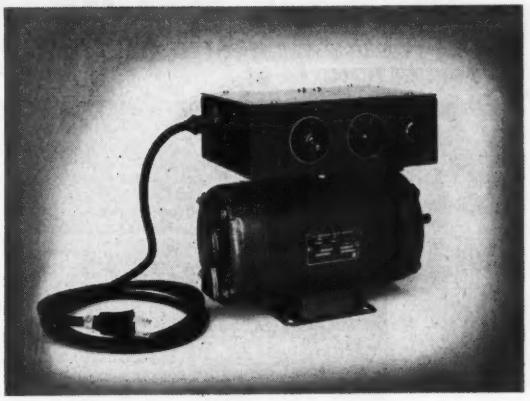
R-f. Power-measuring Equipment

New power-output equipment tests any air-cooled tube having power output between 20 and 4000 watts, and at any one of six fixed frequencies—2.5, 7.5, 15, 20, 30, and 60 Mc. Separate regulated power supplies provide anode, screen-grid, and control-grid voltages. Anode supply has maximum output of



3 & 5 Speed SYNCHRONOUS MOTORS

ESPECIALLY SUITED TO LABORATORY USE



Laboratories, experimental and testing departments no longer need several motors for supplying different speeds; nor are complicated gear or other drives required.

Elinco can supply multiple-speed motors with which change of speed is practically instantaneous at the flick of a switch; instantly reversible, too, even from forward at one speed to reverse at a different speed.

Now, one unit can do the job of five . . . saving in original equipment investment and changeover time. Especially designed for experimental, servo, electronic power and audio mechanisms, as well as for general laboratory use.

115 Volt 60 Cycle Single-Phase Multiple-Speed Motors

MOTOR	SPEED	NOM. H.P. RATING	FULL LOAD POWER INPUT	START TORQUE INCH LB.	PULL-IN TORQUE INCH LB.	PULL-OUT TORQUE INCH LB.	CAP VALUE MFD.
GH-371 3 Speed	900	1/100	59	.95	.86	.90	5
	1800	1/60	77	.70	1.00	1.05	5
	3600	1/40	123	.50	.90	.90	8
GGH-492* 3 Speed	900	1/50	125	1.70	1.50	1.60	10
	1800	1/30	174	1.35	2.00	2.30	10
	3600	1/20	250	.90	1.50	1.90	16
GGH-449 5 Speed	600	1/200	64	.50	.65	.65	6
	900	1/100	59	.95	.86	.90	5
	1200	1/75	61	.70	1.25	1.35	6
	1800	1/60	77	.70	1.00	1.05	5
	3600	1/40	123	.50	.90	.90	8

*This motor must be externally cooled if used for continuous duty.

Models GH 371 and GGH 449 available with or without control box; Model GGH 492 motor only.

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MOTORS AND GENERATORS

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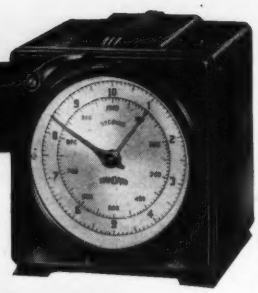

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T-1

Model	Scale Divisions	Totalizes	Accuracy
S-100	1 5 sec.	6000 sec.	±.1 sec.
S-60	1 5 sec.	60 min.	±.1 sec.
SM-60	1 100 min.	60 min.	±.002 min.
S-10	1 10 sec.	1000 sec.	±.02 sec.
S-6	1 1000 min.	10 min.	±.0002 min.
S-1	1 100 sec.	60 sec.	±.01 sec.
MST	1 1000 sec.	360 sec.	±.001 sec.
MST-500	1 1000 sec.	30 sec.	±.002 sec.

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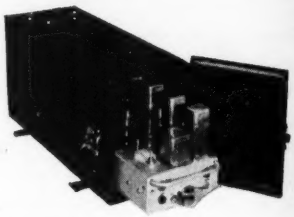
1.5 amp. at 6000 v. Controlled source supplies r-f. power for excitation. Power developed by tube being tested is dissipated in water-cooled resistors and measured by calorimetry. Output can be checked by measuring r-f. voltage developed across load resistance. —*Buck Engineering Co., Inc.,* 37-41 *Marcy St., Freehold, N. J.*

Mention No. 736 when filling out card.

Mine-car Carrier-current Communications System

New carrier-current FM transmitter receiver for mine communications provides two-way voice communication between fixed stations and locomotives

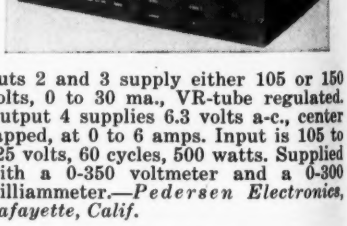


operating on common supply line. Source voltage is provided by 6-v. storage battery charged from d-c. trolley line or motor-generator set on locomotive. Operates at 100 kc. A-f. response 300 to 3000 cps.—*General Electric Co., Schenectady* 5, *N. Y.*

Mention No. 737 when filling out card.

Regulated Power Supply

New "Model 300" regulated power supply features four outputs. One supplies 250 to 320 volts at 0 to 300 ma., with regulation better than 0.07 percent with load, 0.02 percent with line. Out-

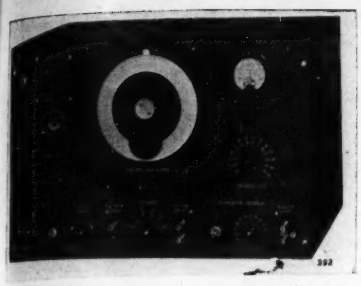


puts 2 and 3 supply either 105 or 150 volts, 0 to 30 ma., VR-tube regulated. Output 4 supplies 6.3 volts a-c., center tapped, at 0 to 6 amps. Input is 105 to 125 volts, 60 cycles, 500 watts. Supplied with a 0-350 voltmeter and a 0-300 milliammeter.—*Pedersen Electronics, Lafayette, Calif.*

Mention No. 738 when filling out card.

Ultrasonic Generator

New "Sonaligner" is ultrasonic oscillator. Outputs are developed at fundamental frequency. Frequency ranges: 10 kc. to 220 kc. in 13 bands. Output maximum of 2 volts from 600 ohms. Crystal check points accurate to 0.01 percent included. Marks every 2, 10, 50, 200 kc. Accuracy is 0.1 percent and

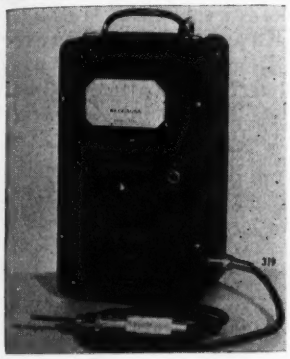


closer at check points. Output level meter and attenuators included.—*Kay Electric Co., Pine Brook, N. J.*

Mention No. 739 when filling out card.

Gaussmeter

New magnetic probe reads magnitude and direction of flux density in air gap as small as 0.025 in. thick and 0.01 sq. in. Flux value is steady reading on



d-c. meter movement as long as probe is held in magnetic field. As probe is nonmagnetic, field is not disturbed. This gives six ranges with accuracy of 2.5 percent from 10 gauss to 30,000 gauss for a-c. and d-c. magnetic fields.—*Dyna Labs, Inc., 132 Lafayette St., New York 13, N. Y.*

Mention No. 740 when filling out card.

Geiger Counter

New "Snooper" is low-priced Geiger counter. Fits in hip pocket. Flashlight battery for power. Supplied with ear-

phone and a radioactive sample. Amplifier gives signal when near radioactivity of any type.—*Precision Radiation Instruments, 4113 W. Jefferson Blvd., Los Angeles 16, Calif.*

Mention No. 741 when filling out card.

Scintillation Scaler

New "Model S-1001" scintillation scaler incorporates: (1) fast linear amplifier with a rise time of 0.25 micro-

A CASE HISTORY OF WHY

- HIGH NATURAL FREQUENCY
- INHERENT FAST RESPONSE
- CONTROLLED READABILITY

ARE IMPORTANT ADVANTAGES OF THE EMERY

FORCE MEASURING SYSTEM

★ SIMPLE COMPACT PORTABLE

THE PROBLEM: A leading manufacturer wished to accurately read loads on a dynamometer for testing engines.

The torque measuring system they were using failed to provide accurate or usable readings; external vibration was present and the system went into resonant vibration at points where accurate readings were most desired. Even minor variations in the load produced erratic readings.

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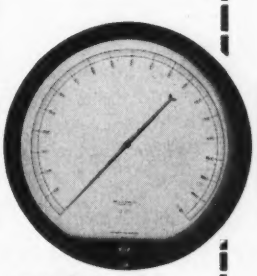
HOW EMERY SOLVED THIS PROBLEM

HIGH NATURAL FREQUENCY: A typical Emery cell has a deflection of less than .005" for full capacity and a high natural resonant frequency of 40,000 cycles per minute. This frequency was far above the external disturbing frequencies encountered in the above problem (and actually far above any such disturbances found in usual applications). A precise and steady dial reading is now obtained over the full range of testing speeds.



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FAST RESPONSE: With the Emery system, full scale indicator reading is obtained in less than ½ second. This inherent speed is unusual and important, but an even greater advantage of the Emery system is its

CONTROLLED READABILITY: Response of the indicator can be that of the inherent fast speed above, or it can be controlled by one simple Emery valve to follow and read load fluctuations, or to provide a steady reading of the mean value of a vibrating load. This control was another major factor in solving the problem described above, and in many other installations.

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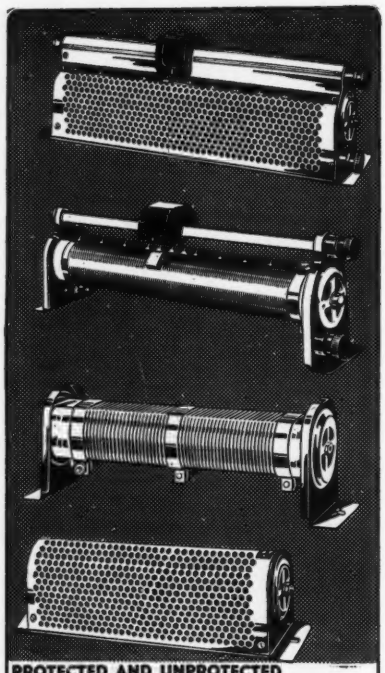

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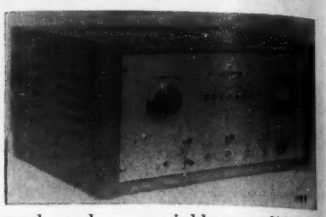
NEW INSTRUMENTS



second and a variable amplification from 0 to 2000 ; (2) true electronic discriminator which accepts pulses from −100 to 50 volts; and (3) regulated high-voltage supply variable from 500 to 2000 volts. Uses reliable Higinbotham scale of 128, interpolation lights, 6-digit electromagnetic register, and 60-cycle test switch for checking performance.—*Nuclear Research and Development, Inc.*, 1094 *Sutter Ave., St. Louis 5, Mo.*

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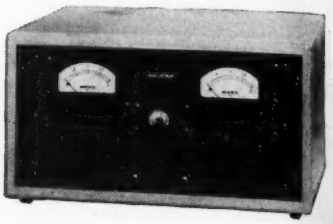
Radioactivity Counter

New "Model 503B Anticoincidence Analyzer" for use with "Screen-Wall Counter" or other type counter tube



counts extremely weak activities with either short or long half-life. Is efficient low-level beta counter.—*Atomic Instrument Co., 84 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 743 when filling out card.

Binary Scaler

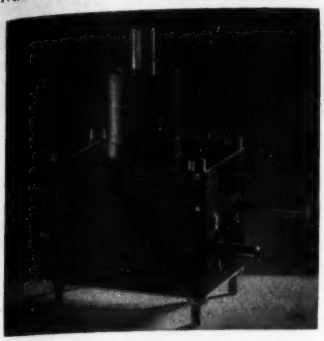
New "Model 4SN1A3" binary scaler incorporates new twin-triode "5963," which is designed for pulsed service. Scaler counts electrical impulses at speeds above 200 kc. per sec. in either binary or decade combinations. Pro-

vides scale of two in self-contained plug-in unit. A 20 to 50-volt negative input pulse of five microseconds duration and 1.0 microsecond rise time produces output pulse of 90 volts with square-wave shape to trigger succeeding binary unit. Power supply specified is 210 volts d-c. at 7 ma.; filament 6.3 volts at 0.3 ampere.—*Dept. N-4, Inquiry Section, General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 744 when filling out card.

Ball and Disk Integrator

New ball and disk integrator is computing element for analog computers and control systems; can generate derivatives, integrals, reciprocals, prod-

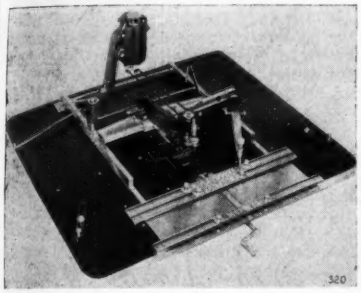


ucts, squares, exponentials, and trigonometric functions. Also useful as control element in closed-loop servosystems and as smoothing or averaging device for fluctuating data.—*Librascope, Inc.*, 1607 *Flower St., Glendale 1, Calif.*

Mention No. 745 when filling out card.

Engraver

New "Model I-S Engravograph" engraves on 25-in. widths and to any length on metal or plastic. Works on pantograph principle and can engrave



15 different sizes from one template. Multiline engraving in one set-up also possible with adjustable copy-holding slides.—*New Hermes, Inc.*, 13-19 *University Place, New York 3, N. Y.*

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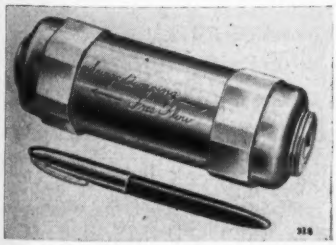
Surge-damping Valve

New surge-damping valves eliminate excessive shock in high-pressure hydraulic systems. Units are adaptable to any hydraulic circuit including at ports of 4-way valves. Valve adjusts automatically to any working pressure, requires only fraction of second to act. Valve is normally closed; opens gradually as pressure is applied to inlet side;



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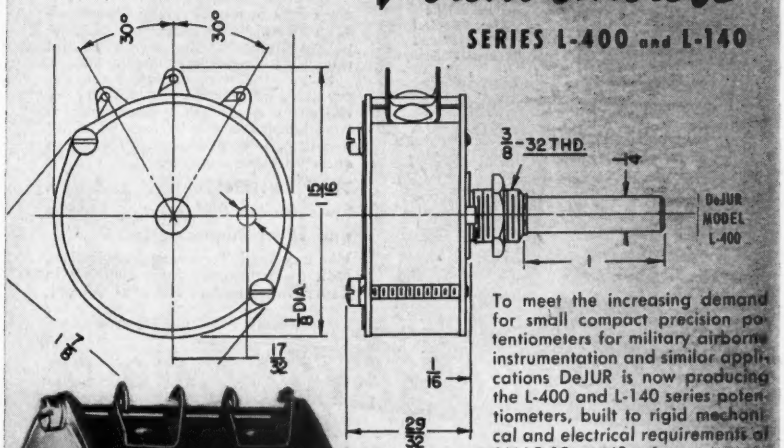

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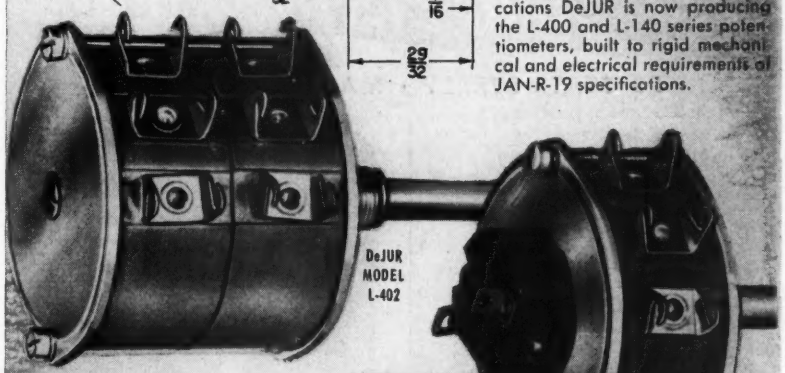

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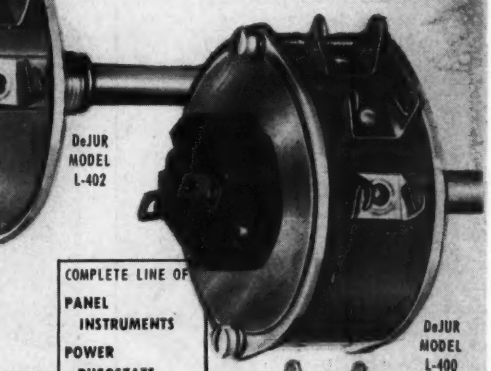

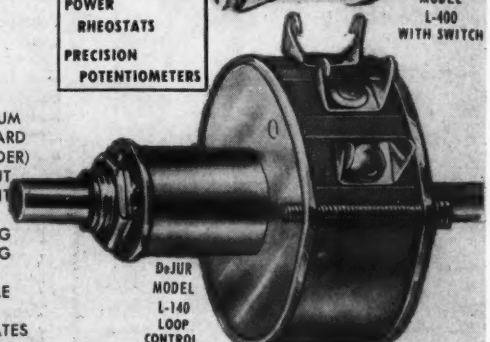

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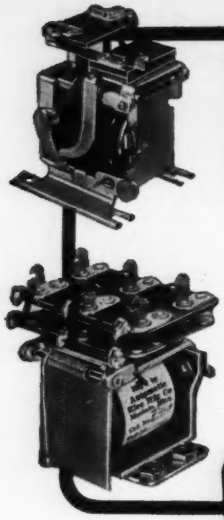

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resets quickly. Valve requires no manual adjustments and has no external drain; opens at slower rate at high pressures than at low pressures when subjected to sudden surges. Rate of flow increases as pressure in outlet line approaches that at inlet side.—*Denison Engineering Co., Columbus, Ohio.*

Mention No. 747 when filling out card.

3-in-1 Drill

New "Screw-Mate" twist drill matches body shape of corresponding size wood screw. Will countersink, drill shank clearance, and drill tapered pilot

hole in one operation. Tapered pilot hole allows even first threads of wood screw to hold. Made from hardened high-tungsten steel.—*D. R. Carner Co., Inc., 106 Hospital St., Providence, R. I.*

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New "No. 788" heavy-duty valve has enclosed gear-reduction drive, extended shaft, and floor stand. Water pressure is sealed by Babbitted seat in body and Monel or stainless steel welded to periphery of valve disk. Remote, automatic, or semi-automatic controls available.—*R-S Products Corp., 4600 Germantown Ave., Philadelphia 44, Pa.*

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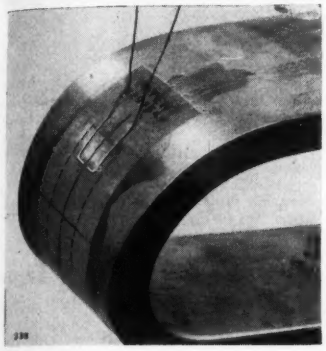
Strain Gage

New "Type PA-3 Post-Yield" SR-4 strain gage measures strains up to 10 percent. Has flat-grid paper-base construction and requires special air-dry-



ing cement. Resistance is 120 ohms; gage factor is 2.0; gage length is 0.815 in.—*Baldwin-Lima-Hamilton Corp., Philadelphia 42, Pa.*

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Pyrometer Supplies

New series of pyrometer supplies includes (1) cast-iron closed-end protecting tube for molten-aluminum applications, in 12 to 36-in. lengths; (2) two-conductor, 24-gage copper-constantan thermocouple wire with moisture-proof polyvinylchloride insulation, and range from minus 20 to plus 225 F.; (3) portable removable-tip immersion thermocouple for molten steel in foundry ladles, which gives readings in 15 to 25 sec. of immersion time in steel having carbon content of 2.5 percent or more, from 2,400 to 2,900 F.; (4) 20-gage JX and KX two-conductor insulated extension-wire in both iron-constantan and chromel-alumel components, insulated with enamel and covered by asbestos and Fiberglas braid; and (5) one-inch, I.P.S. resistant protecting tube for thermocouple protection to 1,800 F.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Philadelphia 44, Pa.*

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Part Winding Starters

New "Bulletin 736" a-c. part winding starter is for use with motors which employ two separate parallel windings, star or delta, to obtain increment starting. Consists of two across-the-line starters and pneumatic timing mechanism mounted below one starter and operated by starter's solenoid plunger. Pressing "start" button immediately

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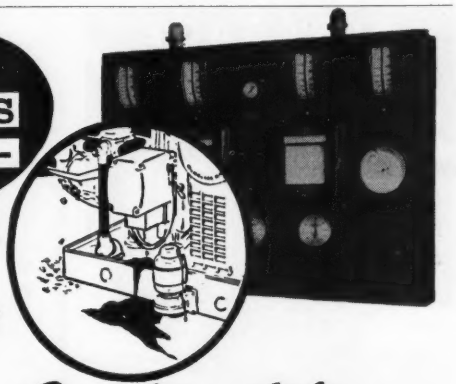

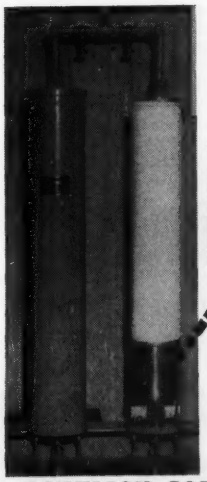

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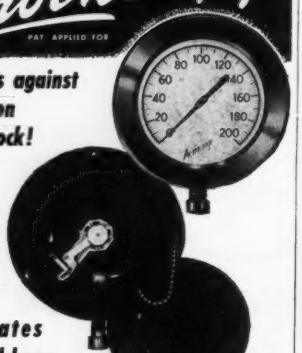

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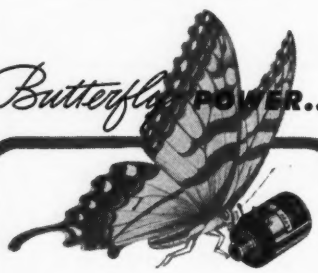

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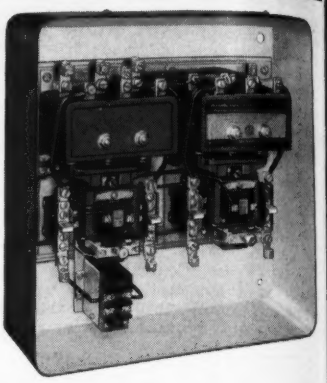

closes first starter. Timer energizes second starter after a few seconds. With both starters closed, full line current is supplied to motor through both windings, each using 50 percent of total current.—*Allen-Bradley Co., Milwaukee 4, Wis.*

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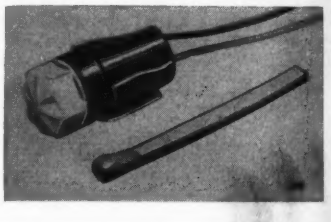
Miniature Indicator Light

New "86L" miniaturized 6-v. light can be viewed from any angle; is 0.75 in. in length and less than 0.37 in. in



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diam. Pushes into "S" drill hole (0.348-in. diam.). Unscrew lens to remove bulb. Furnished with leads to any length.—*Alden Products Co., 117 N. Main St., Brockton 64, Mass.*

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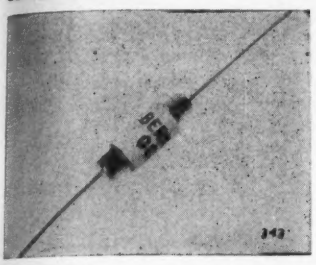

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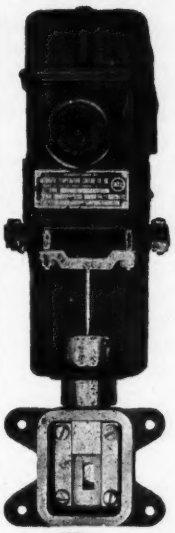

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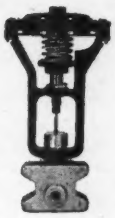

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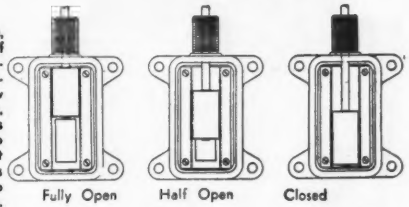

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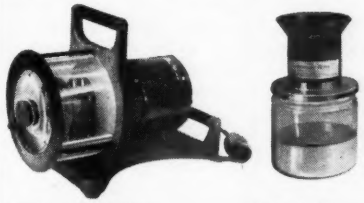

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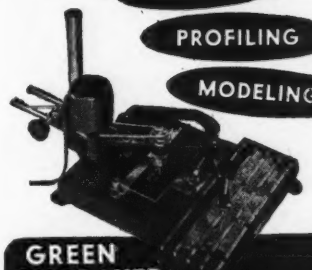

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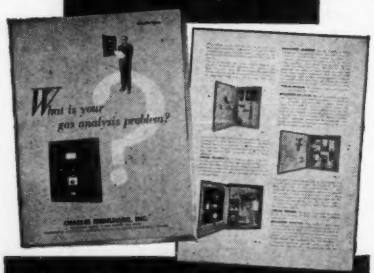

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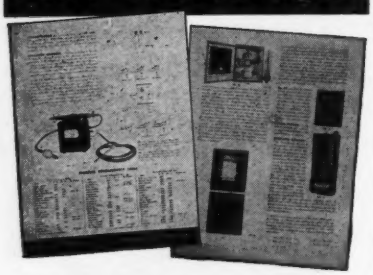

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THERMOCOUPLE SYSTEM FOR MOLTEN METALS

Continued from page 770

the points indicated. The thermocouple was immersed for a normal reading in a bath at a temperature of 2970 deg. F. Readings of the three extra thermocouples were taken at one-minute intervals beginning at 2 minutes after the instrument alarm sounded. All times were checked with a stop watch. The No. 1 couple reached a maximum temperature of 495 F. after 13 minutes, whereas No. 3 couple did not go above 85 F. at any time.

Careful handling of the platinum thermocouple is essential to long life. They should not be disturbed unless their accuracy is doubted or the immersion unit is returned to the shop for repairs. When thermocouples are removed from immersion units, they are kept straight by storing them in long wooden boxes. When returned to the Instrument Shop, the lead wire is unsoldered, the insulators removed, and the wire examined for visual evidence

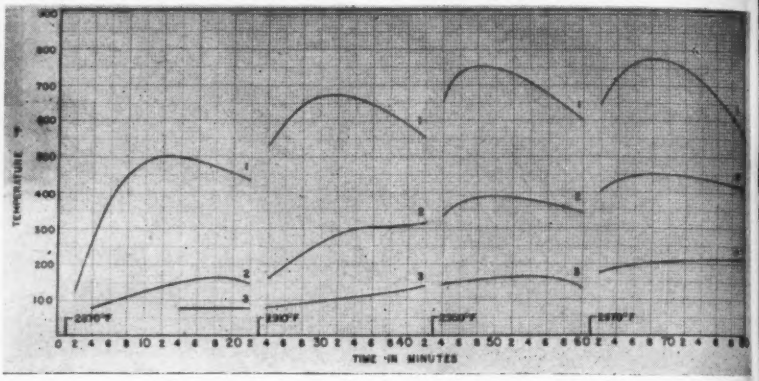

Fig. 6. Temperature-gradient curves for successive readings.

Fig. 6 shows the body-temperature gradients of the thermocouple when four consecutive readings were taken in a period of only 61 minutes. This test proved that the No. 3 thermocouple location was safe to use. As a result of these tests, a minimum thermocouple length of 5 feet is used to eliminate completely the possibility of ever having thermocouple-compensating-lead-wire connection rise to 250 deg. F.

The thermocouples are checked for accuracy while in service by the comparison method. A man from the Instrument Department takes a reading with an immersion unit which is being used by the open-hearth melters. This reading is recorded on the Speedomax. The same man then uses a unit of known accuracy and takes another reading. This is also recorded on the Speedomax. Both readings can be taken in a minute or less and the chart readings compared. The units have been found to be accurate within ±10 deg. F. to 2950 deg. F.

of deterioration or contamination. If necessary, the wire is annealed and fluxed before it is calibrated. All platinum thermocouples are calibrated in a check furnace before being used in the open hearth.

Instrument men are responsible for the maintenance and repair of the complete setup, from the quartz tip to the Speedomax Recorder. The melters take all routine temperature measurements, which are an average of three readings per heat.

This thermocouple system is light enough to be handled by one man; it is portable; it can be stored; and it withstands the average abuses of a steel mill. The user of the equipment need not be a pyrometrist, and it is capable of being used for many consecutive immersions without the need for waiting to cool. Most important of all, the thermocouple system is an accurate and reliable temperature-measuring device for the open-hearth furnace.

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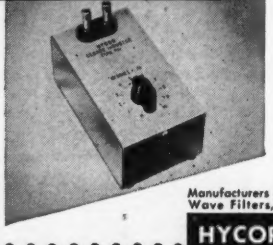

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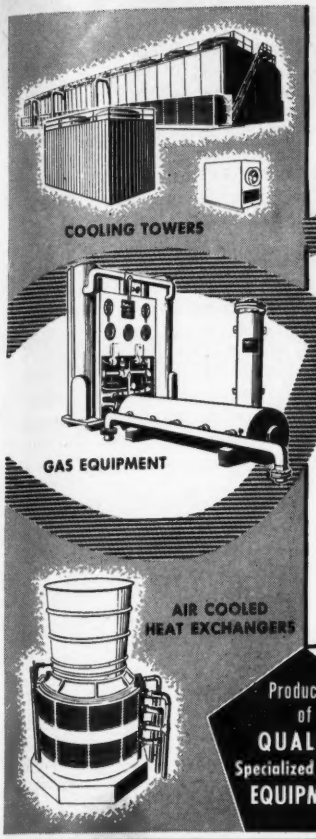

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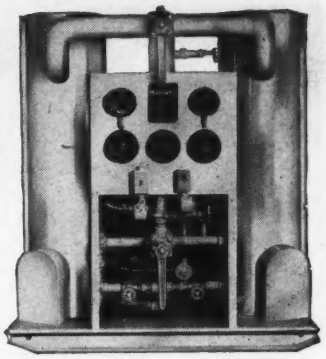

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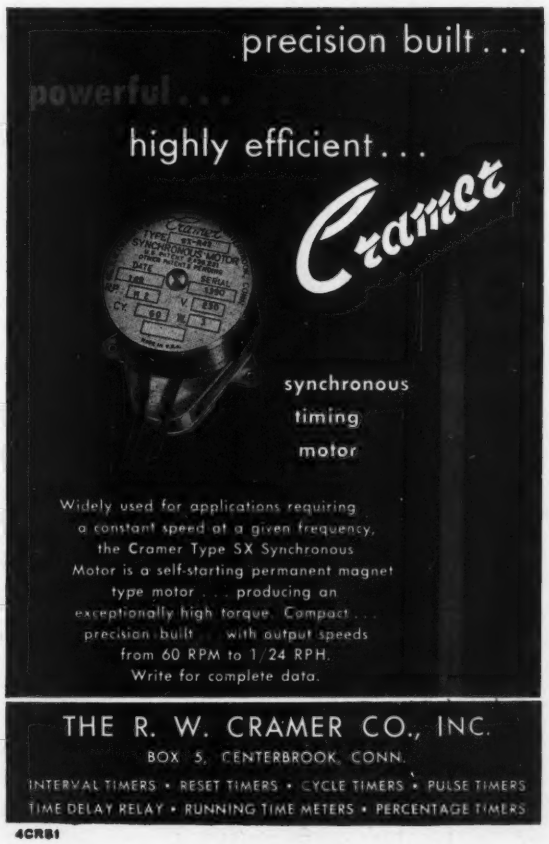
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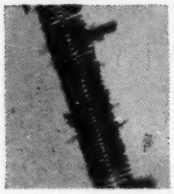

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This enlarged photo shows carbon and oil impurities clogged in old-style unprotected filament after chemical or exhaust gas analysis. Result is changed resistance, inaccurate readings, after short use.

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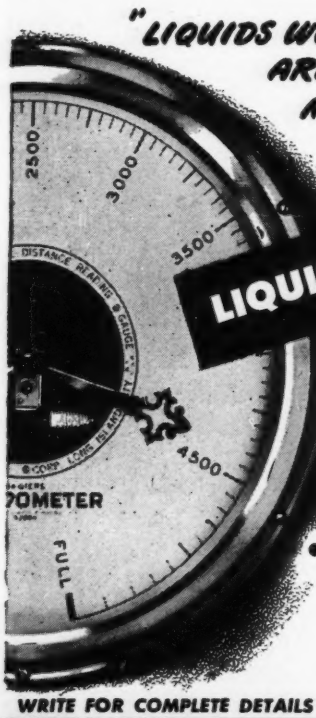

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Continued from page 762

cells can not be recharged. The most common type of primary cell is the familiar dry-cell battery (Fig. 5A.) Secondary cells, however, use a reversible reaction and, therefore, can be recuperated ("recharged" in the vernacular) by sending a current through them in the opposite direction to that during discharge. The lead storage cell is the most familiar type of secondary cell (Fig. 5B).

Motor generators convert mechanical power into a-c. or d-c. electrical power. Motor-generators employ a rotating armature in a magnetic field (or a rotating field and a stationary armature) to induce potential in the armature. The potential induced in the armature can be collected with slip rings at each end of the armature to produce a-c. output (Fig. 6), or the potential can be collected with a single split-ring, called a commutator, to produce pulsating d-c. output (Fig. 7). This mechanical-electrical method is used to produce the familiar 110-volt a-c. and d-c. household and industrial currents.

Peak, Average, and Effective Values

As alternating current varies continuously, it is necessary to define what is meant by a given amount of a-c. potential or current. Peak, average, and effective values are the commonly-used values (Fig. 8).

Peak value is the maximum excursion in potential or

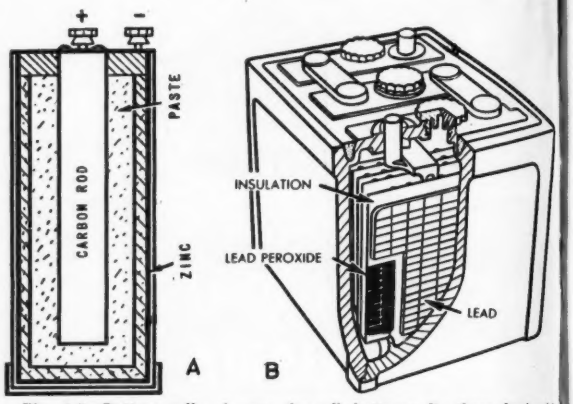

Fig. 1-5. Battery cells. A, one dry-cell battery; B, three lead-acid storage cells in a battery.

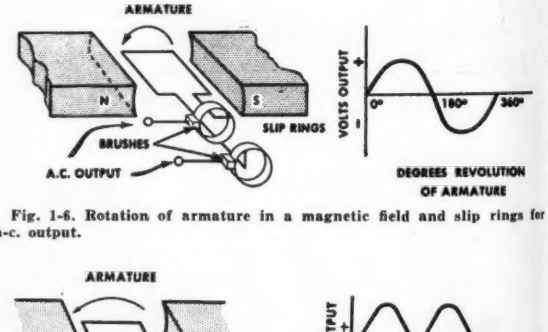

Fig. 1-6. Rotation of armature in a magnetic field and slip rings for a-c. output.

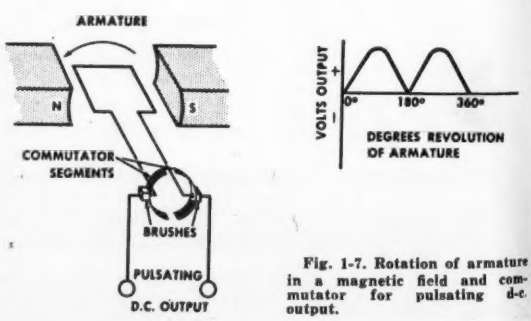

Fig. 1-7. Rotation of armature in a magnetic field and commutator for pulsating d-c. output.

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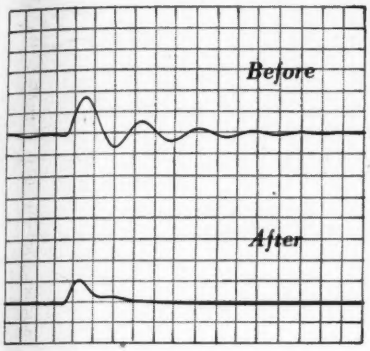

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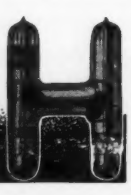

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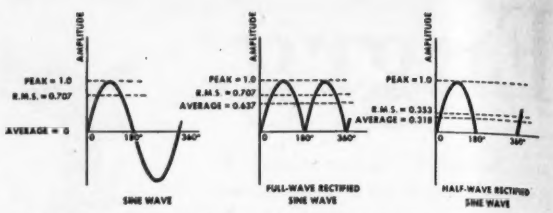

Fig. 1-8. Peak, average, and effective values of a sine wave, a full-wave rectified sine wave, and a half-wave rectified sine wave.

current. This value is important in rectification and power-supply design.

Sometimes the *average value* of a current is desired. This is equal to the direct current that transports the same amount of charge during the same interval of time as the varying current. The average value of a pure sine wave is zero because positive and negative values are equal. A full-wave rectified current, however, has an average value equal to $2/\pi$, or 0.637 times the maximum value (I_{max}). The average value of a half-wave rectified current is $1/\pi$ or 0.318 I_{max}. Most a-c. instruments of the rectifier type respond to the average a-c. value of the current.

The *effective value* of a varying current is equal to the direct current that, flowing in the same resistance, produces the same average power dissipation, or heating effect. The heating effect of a current is proportional to the square of the current and is independent of the direction of current flow. Therefore, the effective value of an alternating current is the square root of the average value of the squared current. Stated briefly, effective value is the square root of the average square. This is abbreviated to rms., or root mean square. Unless otherwise specified, a-c. voltages or current are rms. values. The rms. value of a current is equal to $\sqrt{2}/2$, or 0.707, times the maximum value. Similarly, I_{max} equals $\sqrt{2}$, or 1.414, times the rms. value.

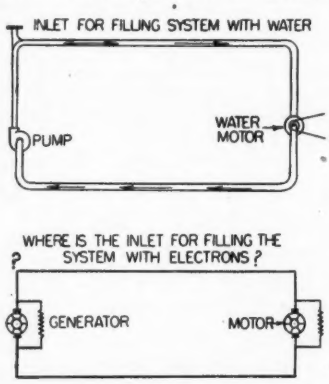

Fig. 1-9. Analogy between an electric and a hydraulic system.

The scales of a-c. instruments usually are calibrated in rms. volts or amperes. Instruments such as thermocouple instruments, which use the heating effect of current as a basis of operation, respond to rms. value directly. Such instruments respond to direct current or rms. alternating current and are independent of frequency. In most a-c. instruments of the rectifier type the scale is calibrated in rms. value, although the instrument responds to the average value.

Analogy between Electric and Hydraulic System

Fig. 9 shows a pump forcing water through a water motor and a generator forcing electricity through an electric motor. The two systems are similar in many respects.

The flow of water in the hydraulic system is analogous to the flow of electrons in the electric system. The pressure developed by the pump between the inlet and outlet is the driving force. Similarly, the potential difference between the generator terminals is the driving force.

As water is incompressible, the motor starts the moment

the pump starts. Thus the pressure is transmitted through the water pipe at a much faster rate than the flow of water. Similarly, the potential in the electric system is transmitted from generator to motor at a much faster rate than the flow of electrons in the conductors. The potential travels at the speed of light, which is so rapid that it is possible to disregard the time lag in all circuits except ultrahigh-frequency circuits. Thus, if the generator develops 115 volts, you can assume that the 115-volt potential appears across the motor at the instant the generator is connected to the line.

There is an obvious difference between the hydraulic and electrical systems. Whereas the hydraulic system must be filled with water from an external source, the electrical system requires no such source. This is because the metals in the electrical system provide the electrons. A current flows in a metallic conductor and not through the air space around the conductor because the metal supplies an enormous number of free electrons, whereas the molecules of air have few free electrons.

Relation between Electricity and Magnetism

One of the earliest discoveries about electricity was that an electric potential is induced in a conductor when the conductor is moved in a magnetic field. This is the basic principle of operation of motor-driven generators (Figs. 6 and 7). When the conductors of the armature cut the lines of flux of the magnetic field, potentials are induced in the armature. These potentials cause currents to flow in a load connected to the output.

A second early discovery about electric current was that there always is a magnetic field around the current. This fact is demonstrated simply by bringing a magnetic compass near a wire in which current flows. The interaction of electric and magnetic fields is important in the operation of inductors and radio waves. As a radio wave is made up of a moving electric and magnetic field, it is called an electromagnetic wave.

TEST ITEMS FOR THE ELECTRICAL NATURE OF MATTER

1-1. Brownian motion is known as
- (a) electron motion
- (b) thermal motion
- (c) kinetic energy
- (d) potential energy

1-2. Brownian motion helped to prove that
- (a) kinetic energy equals $\frac{1}{2}mv^2$
- (b) the molecular weight of water is 18
- (c) atoms are composed of electrons
- (d) all molecules in matter move

1-3. The mass of the sodium atom was first derived by
- (a) use of the kinetic-energy formula
- (b) direct measurement
- (c) use of Avogadro's number
- (d) spectrographic methods

1-4. The volume of an atom was first derived by
- (a) direct measurement
- (b) use of Avogadro's number
- (c) spectrographic methods
- (d) use of Brownian motion

1-5. An ion is
- (a) an electron
- (b) a current
- (c) a charged atom
- (d) a neutral atom

1-6. Normally, an atom or molecule is electrically
- (a) charged positively
- (b) charged negatively
- (c) neutral
- (d) ionized

1-7. The smallest known unit of electric charge is the charge on one
- (a) atom
- (b) molecule

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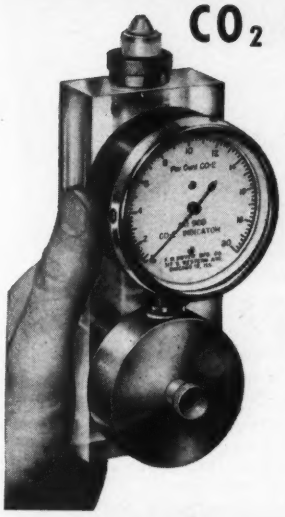

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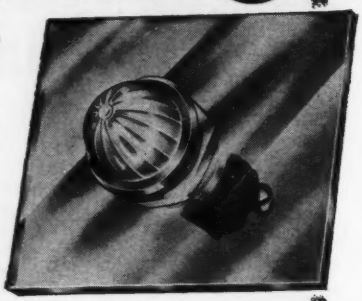

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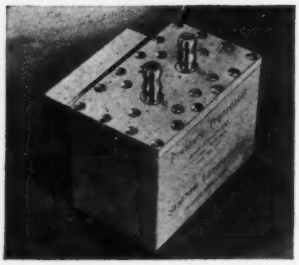

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SCIENTIFIC INSTRUMENTS

12401 West Olympic Blvd. Los Angeles 64, California

(c) electron
(d) microampere

1-8. If an electrically uncharged object loses electrons which are not supplied from an external source, the body becomes
(a) deionized
(b) neutral
(c) charged negatively
(d) charged positively

1-9. Ultraviolet light differs from ordinary visible light in that the former causes irradiated bodies to emit electrons
(a) only when heated
(b) in smaller numbers
(c) more readily
(d) of less penetrating power

1-10. The phenomenon by which bodies emit electrons when illuminated by ordinary light is called
(a) photometry
(b) conductivity
(c) photoelectricity
(d) thermionic emission

1-11. Thermionic emission is like photoelectricity in that both phenomena pertain to
(a) heating of an object
(b) Brownian motion
(c) irradiation of an object with light
(d) emission of electrons from an object

1-12. The mass of an electron was first derived by
(a) using the ratio of charge to mass
(b) direct measurement of one electron
(c) using the kinetic-energy formula
(d) weighing a known number of electrons

1-13. The lightest known mass is the mass of
(a) one electron
(b) one hydrogen atom
(c) one neutron
(d) one proton

1-14. Rutherford's experiments led him to conclude that most of the volume of an atom is occupied by
(a) electrons
(b) protons
(c) neutrons
(d) empty space

1-15. According to the modern theory of atomic structure, as first postulated by Niels Bohr, the electrons in an atom move
(a) in straight-line paths
(b) only when excited by ultraviolet light or heat
(c) inside the nucleus
(d) in orbits around the nucleus

1-16. A positron differs from a proton in that the former has
(a) smaller charge
(b) smaller mass
(c) larger mass
(d) larger charge

1-17. The nucleus of the simplest atom, the hydrogen atom, is
(a) one electron
(b) one proton
(c) one proton and one neutron
(d) two protons and two neutrons

1-18. An electric current is the flow of
(a) electrons only
(b) positive ions only
(c) negative ions only
(d) all the above

1-19. The electric current in a metallic conductor is a flow of
(a) electrons only
(b) positive ions only
(c) negative ions only
(d) all the above

1-20. One ampere of current is the flow of 6.3×10^{18} electrons per second through a cross section of
(a) a wire only

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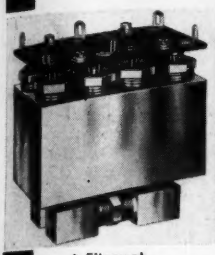

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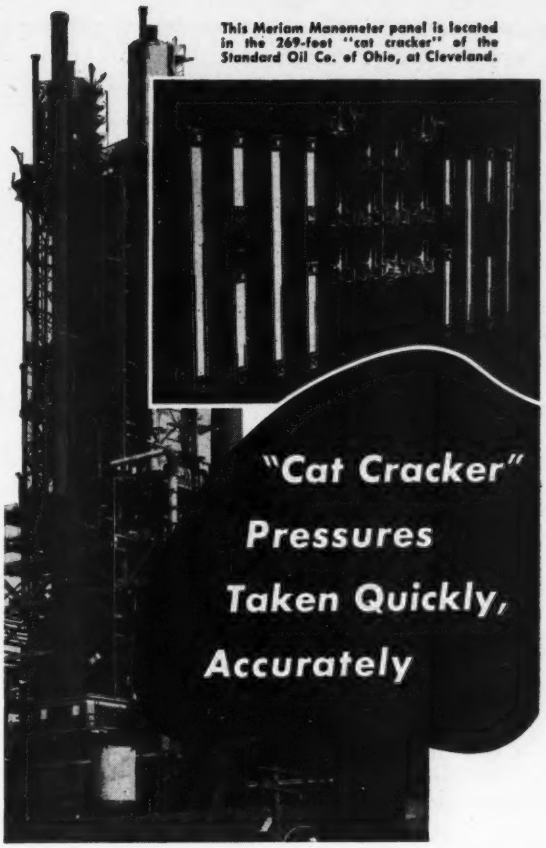

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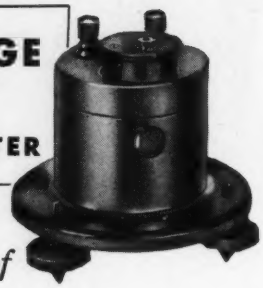

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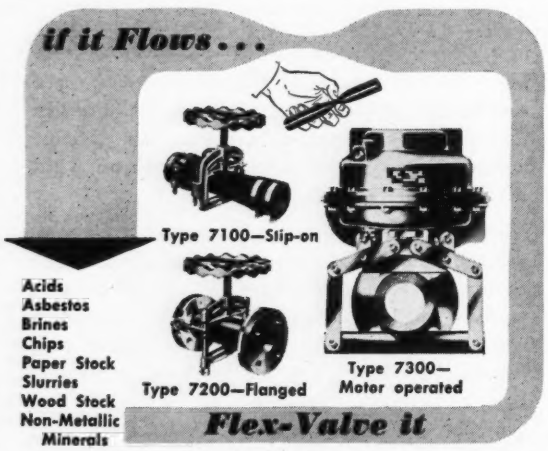

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(b) a gas only
(c) a liquid only
(d) any of the above

1-21. Electron current flows from
(a) positive to negative
(b) negative to positive
(c) negative to more negative
(d) positive to less positive

1-22. The most common reference point of zero potential is
(a) a motor generator
(b) a battery
(c) the earth
(d) all the above

1-23. An alternating current differs from a pulsating direct current in that the former
(a) changes its value from one instant to the next
(b) becomes zero periodically
(c) reverses direction periodically
(d) is produced by a motor generator

1-24. A motor generator with a split-ring commutator supplies
(a) an a-c. potential
(b) a pure d-c. potential
(c) a square-wave potential
(d) a pulsating d-c. potential

1-25. A primary cell differs from a secondary cell in that the former uses
(a) a chemical reaction to produce electrical energy
(b) mechanical energy to produce electrical energy
(c) an irreversible chemical reaction
(d) a reversible chemical reaction

1-26. The peak value of an alternating current is the maximum
(a) amplitude
(b) wavelength
(c) heating effect
(d) effective value

1-27. The average value of a sinoidal waveform is
(a) zero
(b) 0.318 times the maximum value
(c) 0.500 times the maximum value
(d) 0.637 times the maximum value

1-28. The average value of a full-wave rectified a-c. current is
(a) zero
(b) 0.318 times the maximum value
(c) 0.500 times the maximum value
(d) 0.637 times the maximum value

1-29. The effective value of an alternating current is based on
(a) average value
(b) maximum value
(c) frequency
(d) heating effect

1-30. Scales of a-c. instruments usually are calibrated in
(a) average value
(b) rms. value
(c) peak value
(d) rectified a-c. value

1-31. The pressure which forces current through an electric circuit is called
(a) potential
(b) voltage
(c) emf.
(d) all the above

1-32. The source of the electrons in an electric circuit usually is
(a) heat
(b) light
(c) the metal in the circuit
(d) an external tank of electrons

1-33. The motor-driven generator develops a potential in the armature when the armature is rotated in
(a) an electric field
(b) a magnetic field
(c) an electromagnetic field
(d) any of the above

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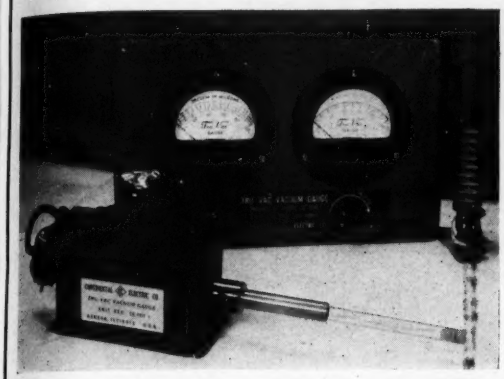
Model 6



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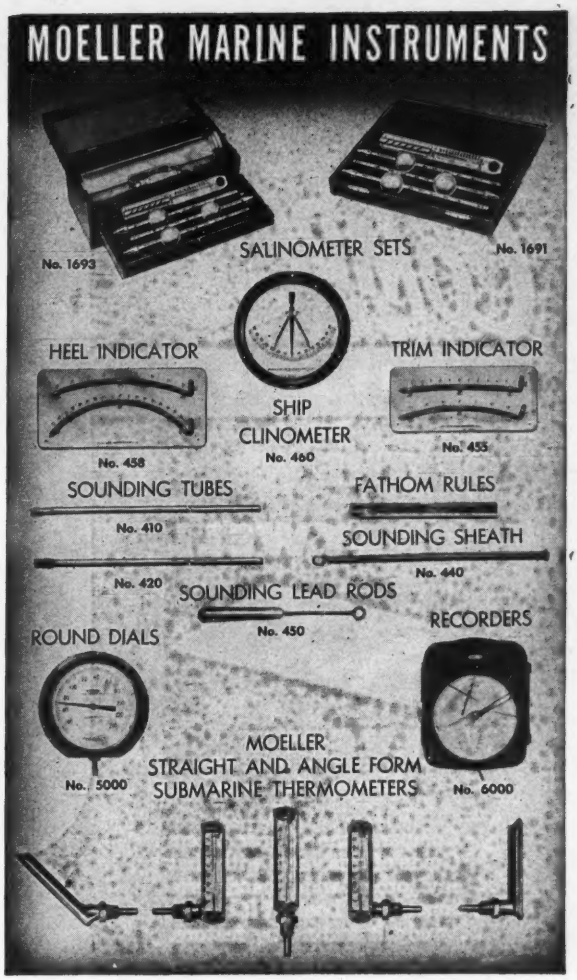

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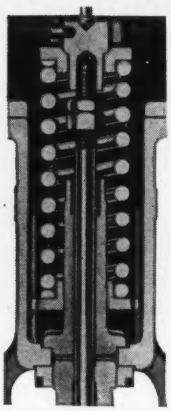

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By C. A. Richardson and A. O. Radke

THE SECRETARY'S PAGE

Ideas from the Sections

I HAVE just received a letter from W. A. Spangenberg, Publicity Chairman of the Presque Isle Section, who reports on several plans which are being put into effect by the Presque Isle Section, ISA, for the coming 1951-52 meeting year. In the interests of transmitting these ideas for possible use by other Sections, I am below outlining some of the plans reported.

Mr. Spangenberg writes:

"Our new Program Chairman, Mr. D. H. Wiley of the American Meter Co., has a novel plan for the coming season which we hope will increase our meeting attendance. Plans are being made to have copies of all the meeting lectures printed and distributed to our members so they can file them for future reference. This will be called our "Year Book" and will be compiled under the direction of Mr. R. B. Gray who gave us this suggestion.

"Another new committee which is being formed is the "Greeters Committee," who will meet our members and guests as they arrive at meetings and pin a name plate on each lapel. This should help the sociability of the meeting.

"An Instrumentation Discussion Period, under the Chairmanship of Mr. H. H. Schroyer of the American Meter Co., is also being instituted by the Section. This will be a 15 minute portion of each meeting program allotted to the discussion of current instrument problems of interest to the members. This will afford a formal opportunity to exchange ideas of useful measurement techniques.

"Another aid which we are planning to inaugurate during the coming meeting season and which has been done with great success by other Sections, is the printing of a program booklet which will list the meeting dates, places, speakers and subjects for the meetings of the '51-'52 year.

"The Presque Isle Section now has an intense membership drive in full swing to contact all companies who employ instrument men in the Erie area. The Membership Committee is convinced that the area should contribute many more members than it does, and they are busy working to make the potential member an actual member."

The Section also is sending two representatives, D. H. Wiley and R. B. Gray, to the Houston meeting and has decided to have these men report on the highlights of the National meeting. This technique has been used many

Continued on page 807

Section Secretaries, Meeting Data and Programs

AKRON
Fred Appel, 932 Columbia Ct., Barberton, Ohio. Tel: SH 3440
Fourth Tuesday, 7:30 P. M., Akron Y.W.C.A.

ALBUQUERQUE
W. E. Bostwick, 2615 Sandia Dr., Bel Air, Albuquerque, N. Mex.
First Monday, Meeting at 8:00 P.M., Science Lecture Hall, Univ. of N. M.

ARUBA
E. H. Pfeffer, P.O. Box 291, c/o Lago Oil & Transport Co., Ltd., Aruba, N.W.I.
First Tuesday, 7:15 P. M., Engr's Club.

ATLANTA
D. M. McRae, 150 Nassau St., Atlanta, Ga.
Fourth Monday, Meeting at 7:45 P.M., Ga. Institute of Technology.

BALTIMORE
W. A. Dickinson, 2716 Dunbrook Ct., Baltimore 22, Md. Tel. Dundalk 2272J
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
John Q. Bass, 1517 Longwood Dr., Baton Rouge. La. Tel: 3-0283
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Last Wednesday, Dinner at 6:30 P. M., Meeting at 7:00 P.M., 99 Club, 99 State St.

CALIFORNIA
D. C. Duncan, Helipot Corp., 916 Meridian Ave., S. Pasadena, Calif. Tel: SY 4-8439
Second Wednesday, Dinner at 6:30 P. M. Meeting at 8:00 P.M., Carolina Dines.

CENTRAL ILLINOIS
H. R. Getz, 723 Laura Ave., Peoria 5, Ill.
First Wednesday, Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Richard F. Rieman, 3550 Euclid St., Indianapolis, Ind. Tel. CH 7462
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
Karl W. Robertson, Minneapolis-Honeywell Reg. Co., 121 Onondaga St., Syracuse.

CHARLESTON
Fred Gilmer, 418 Beech Ave., Charleston, W. Va.
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Hotel.

CHICAGO
Floyd E. Ertsman. Rm. 1490 Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Shoreland Hotel.

CHINA LAKE
A. H. Staud, 1004 Michelson Lab., USNOTS, China Lake, Calif. Tel: 77882
Fourth Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS.

CINCINNATI
R. J. Eichner, 1900 Courtland Ave., Norwood 12, Ohio. Tel: Jefferson 3130
Second Monday, Dinner at 6:30 P.M., Eng'r. Society Hqs.

CLEVELAND
A. E. Ehrke, 5805 Euclid Ave., Cleveland, Ohio. Tel: Ex 1-5454
Fourth Wednesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, E. 19th St.

COLUMBUS
E. H. Chandler, 91 E. Como Ave., Columbus 2, Ohio.
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecilia St., Gumberland, Md. Tel: 583-W
Tuesday after Fourth Monday, 8:00 P. M., Dinner at 6:30 P. M., Algonquin Hotel.

DETROIT
A. W. Brueckner, 5556 S. Clarendon Ave., Detroit 4, Mich. Tel: TYler 6-9511.
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
W. R. McKegg, c/o Gen. Engrg. & Consulting Lab., G. E. Co., Schenectady, N. Y.
First Tuesday, 8:00 P.M., Dinner at 6:30 P.M.

GULF COAST
W. N. Sloan, E. I. Du Pont de Nemours & Co., Orange, Texas. Tel: 8411 Ext. 444
Third Tuesday. Meeting at 7:30 P.M., Lamar College, Beaumont, Texas.

HOUSTON
I. K. Farley, 2123 Travis St., Houston, Texas, Tel: Charter 2511.
Last Monday, 8:00 P. M., Engineers Club.

KANSAS CITY
H. H. Schmall, 3706 Benton Blvd., Kansas City 3, Mo. Tel: AR 4808
First Tuesday, 7:30 P.M., U. of Kansas City.

LOUISVILLE
C. M. Bosworth, 203 Arbor Park, N., Lo., Ky.
Fourth Tuesday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
L. E. Henne, Bristol Co. of Canada Ltd., Dominion Square Bldg., Montreal, Quebec, Can.
Last Monday, 8:00 P. M., Mechanics' Institute.

NEW JERSEY
L. H. Ballinger, 2371 Channing Ave., Westfield, N. J. Tel: Westfield 2-0765M
First Tuesday. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 8856 Commonwealth Blvd., Bellerose 6, N. Y. Tel: FI 7-0645
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

NIAGARA FRONTIER
Mrs. James L. Martin, 697 Potomac Ave., Buffalo 22, N. Y. Tel: GR 1450
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
S. D. Stillson, 1324 Everett St., El Cerrito, Calif. Tel. Becon 2-7139
Third Monday, 8:00 P. M., E. Bay Area.

NORTHERN INDIANA
J. Baum Beckman, 547 N. Waller Ave., Chicago 44, Ill. Tel: ES 8-7776
First Wednesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.

OAK RIDGE
J. Lundholm, Jr., Eff. A-3, Apt. 214, Oak Ridge, Tenn. Tel: 5-6539
First Wednesday, Meeting at 7:30 P.M., Knight's of Columbus Hall.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
W. F. Hoag, Phillips Chem. Co., Box 277, Dumas, Texas.
Third Tuesday, Meeting at 8:00 P.M.

PHILADELPHIA
R. A. Trenner, Rm. 306, 3147 Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellvue Stratford Hotel.

PITTSBURGH
W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa. Tel. Express 1-1330.
Fourth Monday, meeting jointly with the Technical Committee on Inspection and Gaging. Dinner at 6:30 P.M., Meetings at 8:00 P.M., Roosevelt Hotel.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P., Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. E. Community Center, East Lake Rd., Erie, Pa.

RICHLAND
R. A. Nederhood, 2003 Trippe St., Richland, Washington. Tel. 5-4442
Second Wednesday, Meeting at 7:30 P.M., American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Monroe 4610R
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
L. J. Hall, 730 Talfourd St., Sarnia, Ont., Canada.
Second Friday, 8:00 P. M., Moose Hall.

SOUTH MICHIGAN
W. J. Sprau, 2509 S. Rose St., Kalamazoo, Mich. Tel: 4-7012.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

ST. LOUIS
W. G. Lee, 4710 Delor St., Tel: FL 8516.
First Wednesday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.

TOLEDO
P. H. Girkins, 418 Waggoner Blvd., Toledo 12, Ohio.
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
N. M. Taylor, 16 Edgewood, Kingsport, Tenn. Tel: 3338J
No definite night, Dinner at 6:45 P.M., Meeting at 8:00 P.M., Hall's Dining Rm., Bristol Hwy., Kingsport.

TULSA
J. J. Fox, Phillips Petroleum Co., Bartlesville, Okla. Tel: 6600 Ext. 501.
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Alden Hine, c/o Pinkney & Hine, 552 Plymouth Bldg., Minneapolis 3, Minn. Tel.: Lincoln 0523.
Fourth Tuesday, Dinner at 6:30 P.M. Cofman Memorial Union, U. of Minn.

WASHINGTON
Raymond E. Miller, 20-224 Naval Ord. Lab, White Oak, Md. Tel: JU 7-6742
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
J. R. McCauley, 18073 Archdale, Detroit 19, Mich.
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
J. E. Charsha, Jr., Hammel-Dahl Co., 1000 Washington St., Wilmington 11, Del. Tel: 2-6694
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA
921 *Ridge Ave., Pittsburgh* 12, *Pa.*

INSTRUMENT ENGINEERS. Chemical company in Wilmington, Del. wants Instrument Engineers with experience in application, selection, installation and maintenance of measurement and automatic control equipment in wide variety of chemical processes. Must travel to plant locations for start-up assistance, diagnosis of plant instrumentation problems, and training of plant instrument forces. Working knowledge of process control theory as applied to pneumatic systems is desirable. Please give education, experience and salary desired in first letter. Box 489.

DEVELOPMENT ENGINEER. To design and develop small computing and control electromagnetic devices such as servo motors, synchros, resolvers, induction generators, torque motors, etc. B. S. in Electrical Engineering, plus five years experience in the development of electromagnetic devices. Salary $6000 to $10000. Location Long Island, N. Y. Box 490.

PERFORMANCE STUDY ENGINEER. To conduct mechanical performance studies (wear, fatigue, function, etc.) on precision mechanical instrument parts such as gears, bearing, etc. B. S. in Mechanical Engineering, plus five years experience or M. S. plus 2 years experience. Salary $5500 to $7500. Location Long Island, N. Y. Box 491.

MEASUREMENTS ENGINEER. (Three) Conducts laboratory tests and measurement studies on precision computer elements at low audio frequencies. Graduate Electrical Engineer with at least five years experience in related areas. Extensive transformer experience desired. Salary $6000 to $8000. Location Long Island, N. Y. Box 492.

DEVELOPMENT LIASION ENGINEER. To serve as coordinator in the design, development and production planning of electro-magnetic rotating components. Knowledge of manufacturing procedure, drafting and organization essential. B. S. in Electrical or Mechanical Engineering with two to five years experience in related areas. Salary $4000 to $6000. Location Long Island, N. Y. Box 493.

Continued on page 810

ISA EMPLOYMENT REGISTER

Sixth Annual Instrument Conference and Exhibit, Sam Houston Coliseum, Houston, Texas, September 10-14, 1951

Seeking a Position in Instrumentation? Registration forms and further instructions may be obtained from the Society Office. Registration by applicants may be made by mail to this office prior to opening of the Conference and Exhibit or may be made in person Sept. 10-14 at the Employment Register Desk, Sam Houston Coliseum. You do not have to be present. Prospective Employers may examine applications and make selection for mail or personal contact. Write now for application card.

Do You Need an Instrument Man? Companies or institutions seeking instrument men are requested to file notice of open positions with the Society Office, prior to the week of the Conference and Exhibit for posting on bulletin board. You do not have to be present. Interested applicants will be instructed to write direct to you.

INSTRUMENT SOCIETY OF AMERICA, 921 Ridge Avenue, Pittsburgh 12, Pa.

IDEAS FROM SECTIONS

Continued from page 805

times before by the Sections, notably, however, by the Aruba Section in 1950. This Section sent a delegate to the Instrument Conference and Exhibit who took his assignment very seriously. His report to the Section subsequently was printed in the "Aruba Section Bulletin." The report was so thorough and entertaining that it was widely read with great interest even by those who had actually attended the meeting. Other Section officers could well consider this idea. Now is the time to appoint delegates to the Houston meeting and to allot them a period in the Fall meeting program for their reports.

Incidentally, for those going to Houston—another caution about hotel reservations: *Make them as early as possible.* The April ISA Journal carried an article on hotels and rates.

Section Annual Reports

I have just received from the new Jersey Section their June 1951 "Report to Members." This is a four-page smooth-paper 8½-by-11-in., printed fold-over which contains, among other reports, an annual report of the Section President, an annual report of the Section Treasurer, and a report by the Membership Committee. The Section has cleverly incorporated into its regular meeting announcement and reporting sheet this worthy end-of-season report to the members. The Treasurer's report is quite detailed and the other reports are comprehensive and thorough in their history of committee activities for the year past. Section members are thus not only kept well informed but should also be proud of the extensive activities reported.

Section Program Chairman might be reminded again to make their reservations through the National Office if they plan to use the film "Principles of Automatic Control" during the coming meeting year. Demand for this film has been extremely heavy and reservations are being made even now for dates well into 1952. By September or October, reservations to suit will be difficult to obtain.

As soon as final Section meeting announcements are received a new supplementary Speaker's List covering the Section speakers and subjects of the past year will go out to the Secretaries. Watch for it.

Fifth Anniversary Membership Campaign

Last year the Society Sections and Membership Committee under the able chairmanship of M. S. Jacobs put into operation a promotion campaign to increase Society membership to over 5,000 members. It was hoped that this figure would be reached before the Fifth Anniversary date of the Society in April 1951. Although this figure was not quite reached, the results of the campaign were highly creditable and the appreciation of all is due those Sections, Committees, and members who wholeheartedly supported this activity and increased their Section membership thereby.

Sections were assigned a quota of new members to be reached, the goal being 15% of their membership total as it stood last year. Here are listed the Sections, their quotas, and the number of new members actually added by each Section.

As can be seen from this list the Richland Section made the greatest increase in new members. Their quota was 10 and they secured 34. This Section will receive a chairman's gavel from the National Society in appreciation of their service. The gavel will be formally presented to the Section Delegate at the Society function during the Houston Meeting.

The individual whose efforts secured the greatest number of new members was Mr. Theodore A. Clark, of the Clark Brothers Instrument Company. Mr. Clark, who has been a charter member of the Wayne County Section ISA since 1946 was responsible for encouraging 12 men to join the Society. He will receive a 10K gold plated Society insignia lapel button as a symbol of the Society's appreciation.

Space does not permit the listing of each Section member and crediting him with the number of new members who joined through him. To all these members, however, and to those who secured new members but who did not receive Sectional or National recognition, is due the sincere thanks of the entire Society.

It is to be hoped that this fine show of Society promotion by the members will continue, campaign or not, and become a fixed habit of the members. No one is in a position to promote the interests of the Society and to increase the membership of his Section more effectively than the individual member in his own working sphere. No single individual or committee is closer to the actual source of potential members than is this individual member. Constant, determined, patient effort on the part of all members, throughout the entire year, is the way to grow. Let us have a permanent membership campaign.

SECTION	QUOTA	NEW MEMBERS
Akron	6	
Albuquerque	9	1
Aruba	6	3
Atlanta	3	4
Baltimore	11	8
Baton Rogue	7	
Boston	16	9
California	25	12
Central Ill.	6	2
Central Ind.	12	
Central N. Y.	3	3
Charleston	10	2
Chicago	51	19
China Lake	6	
Cincinnati	9	4
Cleveland	19	5
Columbus	3	3
Cumberland	2	2
Detroit	10	1
Eastern N. Y.	15	12
Gulf Coast	6	
Houston	20	11
Kansas City	9	7
Louisville	6	7
Montreal	12	
New Jersey	34	30
New Orleans	2	
New York	37	18
Niagara Frontier	14	1
Northern Calif.	15	7
Northern Ind.	3	6
North Texas	3	
Oak Ridge	9	7
Ontario	6	1
Panhandle	7	6
Philadelphia	49	14
Pittsburgh	36	18
Presque Isle	2	1
Richland	10	34
Rochester	11	3
St. Louis	20	4
Sarnia	11	11
South Texas	9	8
Southern Mich.	4	1
Tennessee	7	4
Toledo	4	4
Tulsa	14	3
Twin Cities	5	
Washington	17	11
Wayne County	11	24
Wilmington	11	6

Symposium on Infra-red Instrumentation at Houston Conference

The Pasadena office of the Office of Naval Research has, during the last two years, scheduled a series of symposia on infra-red research to meet the needs of a large number of scientists and research engineers throughout the country who are actively engaged in research and development in the field of infra-red instrumentation, techniques, and applications, both militarily and commercially. These conferences proved so successful that a similar series is planned on a national scale, to be sponsored by the military services and the National Bureau of Standards in connection with the cooperative program on Basic Instrumentation carried on at NBS.

This year the RDB-NBS Symposium on Infra-red Instrumentation will be held in conjunction with the ISA Sixth National Instrument Conference and Exhibit, Houston, Texas, September 10-14, 1951.

The infra-red symposium will be held on September 13th and 14th. A closed meeting will be held in the Naval Reserve Armory in Houston on September 13th. Security clearance is required for attendance at this session.

The open session on Friday, Sept. 14th will be held in the Coliseum and anyone interested is invited to attend. Papers for the open session will include survey on the present status and recent advances in infra-red instrumentation, papers on rapid scanning spectrometers, Golay cells, and a variety of new commerical infra-red equipment.

Third Instrument Maintenance Clinic
Houston, Texas

BY THIS TIME the ISA Instrument Mechanics Maintenance Clinic should no longer be news to Society members nor to those who follow the affairs of the Society.

Two years ago, in September 1949, during the weekend immediately preceeding the opening of the Fourth National Instrument Conference and Exhibit in St. Louis, 195 instrument mechanics and engineers attended sessions of the First Instrument Maintenance Clinic held in the St. Louis Statler Hotel. Ten groups of men attended ten separate, two-hour sessions on the repair, maintenance and installation of the instruments of ten companies who were to begin exhibiting on the coming Monday. Instructors and equipment were provided by the selected instrument manufacturers. Classes ran from Friday noon through Saturday and through Sunday. Late Sunday night, a group of very tired students and instructors called it a day. 195 men had each received 20 hours of instruction.

The response to this first Clinic was overwhelming. Instructors were gratified by the intense, sustained interest and active participation of the students. Students were lavish in praise of the instructors, the teaching methods and the subjects. All were satisfied that the day, or the half-day taken from regular jobs has been more than well repaid. Most students stayed over Monday, attending the Instrument Exhibit and taking advantage of the technical sessions of the Conference.

The Buffalo Clinic

Buffalo in 1950 saw the Second Instrument Maintenance Clinic. Host was the New York State Institute of Applied Arts and Sciences, which generously opened its classrooms and laboratories for the students. The Second Clinic was similar to the original in group-time structure but offered subjects by instrument users. Typical subjects were: primary flow devices, fabrication and calibration of thermocouples, wet and dry meters, typical bridge circuits, strain gages and position indicators.

Again, in two and one half days, each student received 20 hours of instrument instruction. Many of the students had attended the first Clinic and were doubly repaid at Buffalo. Overseas visitors to the Instrument Exhibit made a special point to attend. Professional educators of the Institute marveled as the Clinic unfolded. The technical as well as the local popular press were keenly interested. Applicants had to be turned away. For the second time the Clinic was a complete success.

The Clinic at Houston

This year in Houston, Texas, the Third Instrument Maintenance Clinic will be held on Friday, Saturday and Sunday, September 7th, 8th and 9th. The Sixth National Instrument Conference and Exhibit will open on Monday morning, September 10th.

The Instrument Maintenance Clinic Sub-Committee of the Houston Section General Conference Committee is headed by C. R. Miller of the General Tire and Rubber Company, Baytown, Texas. Mr. Miller's Sub-Committee does liaison work with the National Instrument Maintenance and Operation Committee, and cooperates with them in arranging the Clinic topics and the instructors. The Sub-Committee heads up all the extensive local work in arranging the Clinic, with the help of the National Office.

Mr. Miller's Sub-Committee has already performed outstanding service in making arrangements for the Third Instrument Maintenance Clinic.

Participating Companies

The instrument manufacturing companies who will participate in the Houston Clinic, supplying instructors and equipment, and the subjects they will cover are as follows:

Brown Instrument Division, Minneapolis-Honeywell Regulator Company—*Operation & Maintenance of Brown Electronik;*

Fisher Governor Company—*Displacement Float Type Level Control;*

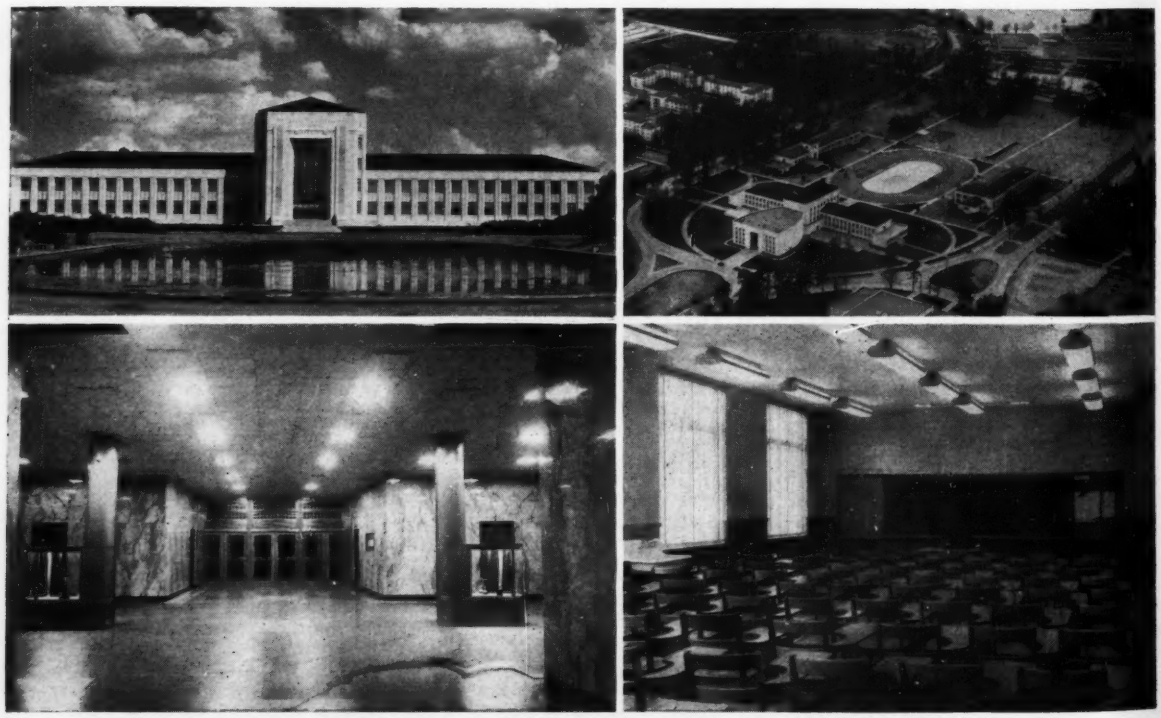
Foxboro Company—*The Dynalog;*

Hagan Corporation—*Boiler Combustion Controls;*

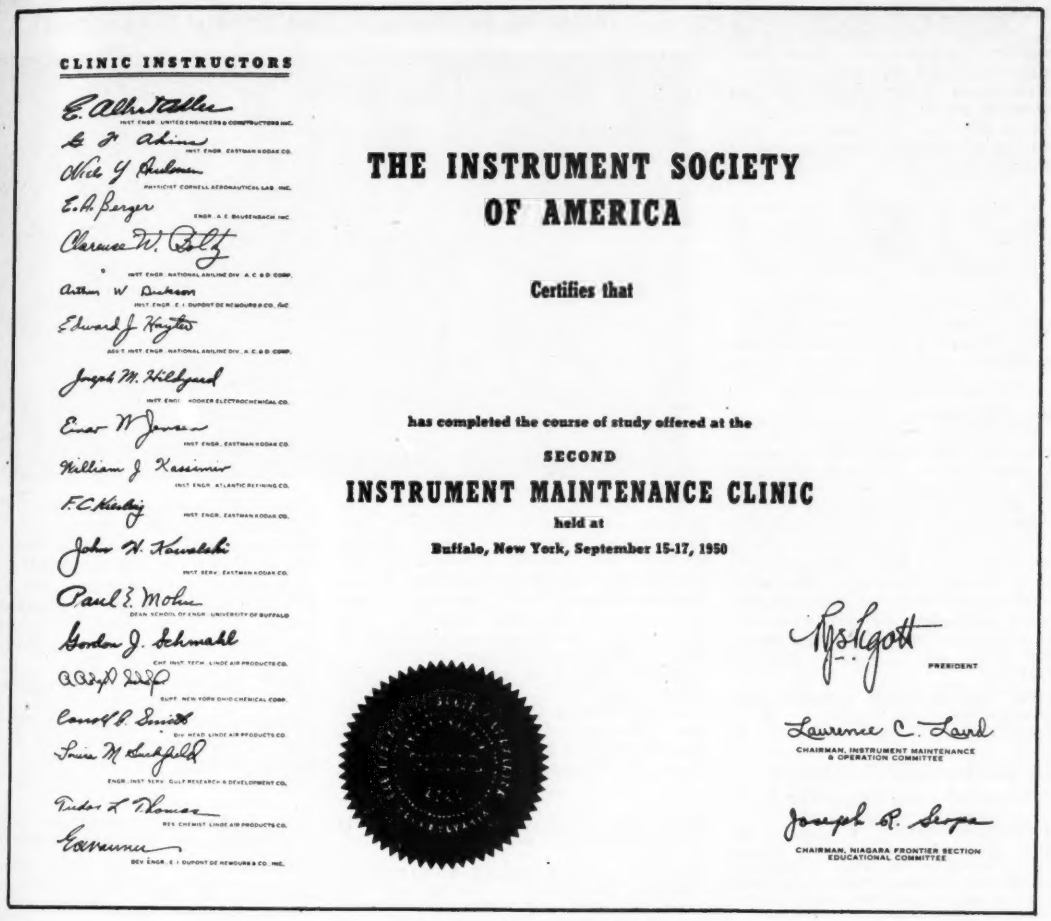
Leeds & Northrup Company—*Pneumatic Control & P. H. Measuring Circuits;*

Manning, Maxwell & Moore, Inc.—*Pressure Gages & Temperature Indicators;*

SCENE OF THE THIRD INSTRUMENT MAINTENANCE CLINIC UNIVERSITY OF HOUSTON



Ezekiel W. Cullen Building (top left) scene of the Clinic. View of campus, University of Houston (top right). Lobby of main entrance, Ezekiel W. Cullen Building (lower left); and one of the Clinic classrooms (lower right).



CLINIC INSTRUCTORS

THE INSTRUMENT SOCIETY OF AMERICA

Certifies that

has completed the course of study offered at the

SECOND

INSTRUMENT MAINTENANCE CLINIC

held at

Buffalo, New York, September 15-17, 1950

PRESIDENT

CHAIRMAN, INSTRUMENT MAINTENANCE & OPERATION COMMITTEE

CHAIRMAN, NIAGARA FRONTIER SECTION EDUCATIONAL COMMITTEE

Clinic Certificate, 1950 Clinic

Mason-Neilan Regulator Company—*Control Valves and Valve Positioners;*

Moore Products Company—*Nullmatic Controller & Nullmatic M. P. Station;*

Republic Flow Meters Company—*Pneumatic Transmitters;*

Taylor Instrument Companies—*The Transet Control System.*

The Sub-Committee has worked to provide a balanced program covering the most timely and popular subjects for the best interest of the students.

The instructors, in covering the subjects, will be guided along these lines: a) maintenance; b) location of trouble, including methods, procedure and equipment needed; c) repairs of the instrument being considered. No instrument will be covered which has not been on the market for 18 months or more. All companies will supply their own operating models, demonstration and accessory equipment.

At the St. Louis Clinic, the instrument companies who participated sent their best men as instructors. The response and comments of the students attested to this. The instructor staff of the Houston Clinic, from all indications received, will again be a selection of the best men in the operation and maintenance field. The companies concerned are selecting their men with extreme care; extensive experience, depth of knowledge, interest, and teaching ability being the requirements. Instructors and assistants are drawn either from the application, project, or service departments, and are generally Chief Engineers or Service Managers.

Registration and Class Hours

The Clinic will begin with registration at noon on Friday, September 7th, and will run six hours on Friday afternoon; on Saturday there will be eight hours of classes; on Sunday six hours of instruction. Actual times are as follows: Friday—1 to 3, 3 to 5, 5:15 to 7:15. Saturday, 8 to 10, 10:15 to 12:15, 1:15 to 3:15, and 3:30 to 5:30. On Sunday: 10 to 12, 1 to 3, and 3:15 to 5:15. Students will be divided into ten groups numbered respectively 1 to 10, and each group will move successively through 10 rooms lettered A to J; the instructors and equipment remaining in the same room and each subject being presented ten times there.

This program presents quite a task to both students and instructors. There is no doubt that it is rewarding.

The Clinic will be held in the modern classrooms of the air conditioned Ezekeil W. Cullen Building on the Campus of the University of Houston. The University has graciously offered to act as Host to the Maintenance Clinic, to its students and instructors. Photos of the campus, the building, and one of the classrooms are shown herewith. The University campus is conveniently reached by bus from downtown Houston.

As has been the custom in the past, all efforts are made to keep travel and living expenses of the students as low as possible. Several transportation plans are now being considered and will be reported on later. Positive steps on economizing on living expenses have been taken. There will be available, in Oberholtzer Hall, (a new dormitory on the campus), limited room space, two and three men per room, to Clinic students at a rate of $2.00 per day per man. Rooms will also be available from the 10th of September through the 14th, if desired. Plans for cafeteria service are not yet definite. Several eating places, however, are within easy walking distance of the classrooms.

Individual Attention Assured

Each class at the Clinic will be limited to 20 men to insure maximum benefit to the student by allowing individual attention to his questions. A small group such as this, by voicing its needs to the instructor, permits great topic-flexibility and better control over course-content; it being the desire of the instructors to adapt their material to best serve the students in each particular group. Lively participation by the class has been one of the outstanding features of the Clinics. It is strongly encouraged. A disciplined informality characterizes class atmosphere.

The Clinic is open to members of the Society and to non-members alike, but due to the heavy demand and the lim-

ited facilities available, the *applications of ISA members and members of the Cooperating Societies are taken first.* Openings remaining are then assigned to non-members. After registration no distinction is made. A registration fee of $3.00 is charged non-members. This fee can be applied toward the man's membership dues if he joins the Society.

To serve as a break in the heavy work load, the Society plans to provide a no-charge entertainment program for students on Saturday evening, September 8th.

Each student who successfully completes the course by attending all sessions will receive a Society certificate to this effect.

Advance Registration

Final registration will be held at noon on Friday, September 7th, in Houston. Advance registration is available by mail to the National Office. In the near future, each member of the Society will receive, along with a Tentative Program of the Conference and Exhibit, an Advance Registration Blank for the Clinic. This blank, if completed and sent to the National Office, will reserve a place in the Clinic for the applicant. Advance registrations will be acknowledged and the applicants supplied with all necessary detailed information.

Further data on Clinic arrangements will appear on these pages as it is developed.

Houston Instrument Convention Committee

The Houston Section General Conference and Exhibit Committee, the group responsible for arranging the Houston Instrument Conference and Exhibit, met again on June 5th in the Houston Chamber of Commerce to iron out some of the final details of the show which is to open on September 10th in the Sam Houston Coliseum.

Shown above, from left to right, seated are: C. R. MILLER, General Tire and Rubber Co.; PORTER HART, Dow Chemical Co.; J. R. MARTIN, Humble Oil and Refinery Co. Chairman, National Meetings Committee; R. E. O'NEILL, Industrial Scientific Co., I. K. FARLEY, Brown Instruments Div., Minneapolis-Honeywell Regulator Co.; and R. C. KING, Dow Chemical Co.

Standing, left to right, are: R. L. SPRINGFIELD, Manning Maxwell and Moore, Inc.; C. W. BATES, Humble Oil and Refining Co.; R. E. HANSON, Leeds and Northrup Co.; G. A. HUBERT, Eastern States Petroleum Co.; W. B. RAWSON, Maintenance Engineering Corp.; W. H. FORTNEY, Humble Oil and Refining Co., and R. RIMBACH, Exhibit Manager.

ISA EMPLOYMENT SERVICE

Continued from page 806

SPECIFICATIONS WRITER. To assist in the preparation of standard material and process specifications governing the design of precision electro-mechanical devices, College graduate with technical degree preferred. Salary $3600—$4700. Location Long Island, N. Y. Box 494.

INSTRUMENT TECHNICIAN. For servicing present extensive equipment; supervising installation of new instruments; assisting in specifications, designs and applications for new equipment. Should have two to five years industrial experience in instrumentation. Will be in charge of department. Salary commensurate with experience. Give complete details in first letter. Location Illinois. Box 495.

INSTRUMENT MECHANIC. Experienced in the installation and adjustment of Steam Plant instruments and automatic combustion controls. Knowledge of electricity essential. Permanent position in Service Dept. of manufacturer. Considerable traveling in the U. S. Give details of background, education and experience. Location near Chicago. Box 496.

INSTRUMENT TECHNICIANS. With five years experience on pneumatic receivers and transmitters. Ability to calibrate all types industrial flow meters. Maintain most types of automatic controllers and put into operation temperature, pressure and level type instruments. Columbia Cellulose Co., Prince Rupert, B. C., Canada. Box 497.

INSTRUMENT MECHANIC. Experienced in pneumatic and electrical controls as used in an oil refinery or chemical plant. $2.22 per hr., forty hr. week, liberal benefit plan and good working conditions. Location St. Louis area. Box 498.

DEVELOPMENT ENGINEER. Electrical Engineer (graduate) with two to four years of experience and with a working knowledge of electronic instruments for the development of resistance welding machinery. Location Western New York. Box 499.

SALES ENGINEER. Leading manufacturer of pressure and temperature gages and industrial instruments wants man 24 to 35 to cover Northern Ohio with Cleveland as base. Car and some sales experience preferably along with instrument lines absolutely necessary. Salary and expenses, excellent opportunity. Give resume of record in first letter. Box 500.

AIRCRAFT INSTRUMENT ENGINEERS. Graduates. Experienced in aircraft and electronic instruments and instrumentation. Large aircraft manufacturer. Location Georgia. Box 501.

GOVERNMENT SERVICES

INSTRUMENTATION SCIENTISTS. A program in basic instrumentation research is underway at the National Bureau of Standards cooperatively sponsored by ONR, Air Force, and AEC, involving theoretical and experimental research, development, design, evaluation, and technical reference work in the broad field of measurement and control instruments. Excellent opportunities are open for qualified scientists and engineers in a broad variety of basic instrumentation problems. Salaries range from $3825. to $7600. per year. Further information concerning these positions can be obtained from W. A. Wildhack, Chief, Office of Basic Instrumentation, National Bureau of Standards, Washington 25, D. C.

To apply for any of the following Federal Agency positions, secure Standard Form 57, "Application for Federal Employment" from your local Post Office or write for the form to the agency involved. Complete the form and mail direct to the personnel office of the agency holding the vacancy.

U. S. NAVAL AIR MISSILE TEST CENTER
POINT MUGU, CALIFORNIA

ELECTRONIC ENGINEER, $4600. Project engineer on P/A test projects. Particular experience in automatic control systems and instrumentation techniques highly desirable.

ELECTRONIC ENGINEER, $5400. Test and evaluate missile guidance systems, instruments and components. Develop testing facilities and testing techniques and participate in the development of guiding systems for missiles.

ELECTRONIC ENGINEER, $4600; PHYSICISTS, $4600; ELECTRONIC TECHNICIAN, $4600. Same as above.

U. S. NAVAL ORDNANCE TEST STATION
INYOKERN, CHINA LAKE, CALIFORNIA

ELECTRICAL ENGINEER $4600. Project engineer concerned with power transmissions and distribution and detail of instrumentation facilities for the ground ranges.

ELECTRONIC ENGINEER $7600. Supervision of a laboratory of physicists, engineers and technicians engaged in research and development program involving electronic devices and instruments for use in ordnance equipment.

ELECTRONIC ENGINEER, $5400. Application of new theories in the field of automatic control and instrumentation. Using extensive knowledge of past and current developments in servomechanisms.

ELECTRONIC ENGINEER, $4600. Electronic research and development in the field of measurement.

ELECTRONIC ENGINEER, $4600. Design and development of electronic instruments for use in free flight ballistics experiments on Fin-Stabilized rockets.

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Research Instrumentation as Applied to the Transportation of Perishable Freight

Refrigerator Car Research — Association of American Railroads

By C. A. RICHARDSON* and A. O. RADKE**

ABSTRACT. This article outlines the development of refrigerator cars employed to protect perishable foods in transit, and discusses the three basic services involved, namely: refrigeration, ventilation, and heat. Construction of typical cars is described; the basic controlled variables of temperature, humidity, and air velocity are discussed; and research work in this field is outlined with several examples of instrumentation employed in a moving "field laboratory" (the train of cars itself). Certain difficulties in testing procedures are analyzed with a view toward possible improvements which might be forthcoming in this important field of instrumentation.

The history of the transportation of perishable freight is not only the history of an industry but in a sense the history of great areas of the United States. The development of the railroad refrigerator car has gone hand in hand with the economic development of many States. This simultaneous growth has had tremendous effects on the health and living habits of the entire country. Probably the most often given example of this effect is the change in status of the orange from a Christmas stocking gift to the almost universal everyday breakfast request for "orange juice, coffee, toast, etc." "Seasonableness" of fresh fruits and vegetables is practically unknown. This revolution in habit was made possible by the refrigerator car.

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Statements and opinions expressed in these articles are those of the authors and not necessarily those of the Society.

THE AUTHORS

C. A. Richardson graduated from Cornell College, Iowa, with a degree in Civil Engineering. Following graduation he practiced Civil Engineering, including railroad location, reservoir location and construction, irrigation projects and the location design of a water system.

In 1915 he was employed by the Pacific Fruit Express Company and worked for them for 30 years. During this period his positions were: Test Engineer, Superintendent of Heater Service and Superintendent of Refrigeration. During his entire time with the Pacific Fruit Express Company, he had charge of their test and research work on the transportation of perishable freight in refrigerator cars in addition to other duties.

In 1946, he became employed by the Association of American Railroads as Chief Engineer of their Refrigerator Car Research Bureau with headquarters in Chicago, which position he now holds.

He is an active member of The American Society of Refrigerating Engineers, The National Association of Practical Refrigerating Engineers, and The American Society of Heating and Ventilating Engineers.

(A. O. Radke is no longer associated with the AAR—no biography is available)

What is the present job of this refrigerator car? It is, in combination with about 130,000 others, to move about 50 million tons of freight some 250 million miles. It moves this in about 2.5 million carloads averaging about 20 tons each. It moves some 30 different classes of commodities, including fresh and frozen fruits and vegetables, canned goods, meat, eggs, and poultry—none of which account for more than 20 percent of the total and only six of which account for more than 5 percent of the total—under a wide range of climatic conditions and seasons and requiring a variety of protective services including intensive refrigeration for frozen foods, ventilation, ice refrigeration, heat and even combinations of these. In order to accomplish this for all commodities in all seasons there are hundreds of "rules" or variations of the three basic services of refrigeration, ventilation, and heat.

The purposes of these statistics is not to amaze or overwhelm, but to illustrate several paradoxes, namely: first, the volume of perishables moved compared to the relatively few refrigerator cars; and, second, the utter simplicity of the refrigerator car itself as contrasted with the complexity of the job.

Construction of Cars

The refrigerator car has been called, sometimes disparagingly, an "ice box on wheels" and essentially it is just that. It consists of an insulated structure with inside dimensions approximately 8 by 8 by 40 ft. The thickness of the "walls" are about 6 or 8 inches and carry 3 to 7 inches of insulation. The lighter insulation of 3 to 4½ inches is ordinarily used in standard cars and the heavier insulation is found in cars used for the transportation of frozen foods.

Ice bunkers, 8 by 7 by 3 feet are located at each end and hold an average of about 11,000 lb. of chunk ice. Two insulated hatches are located over each bunker through which the ice is furnished. The loading space is approximately 33 feet long and two insulated doors approximately 4 to 6 feet wide by 7 feet high are provided on each side at the center of the cars. Many newer types of refrigerator cars are now being equipped with sliding doors. The ice bunkers are open to the loading space at the top and bottom, and hinged floor racks which cover the loading space allow air circulation under and around the load.

Air is circulated through the ice in the bunker either because of the temperature differential or by means of air circulating fans, which force a greater volume of air through the bunkers. These fans are powered by the train movement and consequently operate only when the car is moving. Portable motors can be used to drive the fans at terminals. New air circulating devices are now being developed.

Evolution of the Refrigerator Car

The refrigerator car has evolved throughout the years. It made its appearance in the 1860's as a box car insulated with sawdust. The early cars were developed principally to carry dressed meat and as their success in this field increased, about 1870, experiments with shipments of fresh fruits were made. The refrigerator car, as we know it, evolved in the early 1900's. Since that time the changes have been principally in improvement and refinement of the basic design. Gradually the thickness of the insulation has been increased, the ice capacity increased, and the air circulation improved, first by the introduction of floor racks, wall racks, flues and finally mechanical air circulators.

Greater changes occurred, however, in the services attendant on perishable shipments during this period. Stations for icing of the cars in transit and at origin and destination were increased (1) in number, their efficiency improved by mechanical conveyors for ice; and (2) in size, so that it is now possible to ice hundred-car trains of perishables in an hour or less.

As the shippers knowledge of his product grew through research and experience, he was able to further improve the quality of the product. Precooling, where the product is cooled to proper temperature, either before loading or by auxiliary means in the refrigerator car, was perhaps the biggest advance in improving quality. As the knowledge of the product increased, the carriers were able to meet the new requirements by providing variations and combinations of the three basic services of refrigeration, ventilation, and heat.

Basic Variables to be Controlled

Since we are dealing with living organisms, the basic science in the perishable transportation field is that of agriculture, particularly those branches concerned with the physiology and pathology of plants and plant products. It is the purpose of these branches to reduce and correlate the hundreds of processes and variables which determine the ultimate quality of the product to a few that can to some extent be controlled and measured. In the

case of perishable storage—of which transportation is really an extension—they have reduced the variable to three, namely: temperature, humidity, and air velocity over the commodity or product. Of these temperature and humidity are the most important while air velocity is important, generally, only in the case of low humidities. Temperature controls the metabolism of many of the organisms found with the product, as well as the product itself. Humidity (and air circulation) are of principal importance in preventing moisture loss from the product.

Refrigerator Car Design has been concerned with all of these elements, but particularly with temperature.

The optimum storage temperature for fresh fruits is usually the lowest possible temperature safely above the freezing point, which in most cases means a desirable transit temperature of 30 to 45 F. The principal exceptions to this are the tropical fruits such as bananas and pineapples, as well as lemons and limes. It may be desirable, however, in order to avoid certain decay or disease, and depending on the condition and maturity of the commodity, to ship at slightly higher temperatures. This range (30 to 45 F.) is usually optimum for all vegetables with such exceptions as white and sweet potatoes, pumpkins, squash, and tomatoes which require slightly higher temperatures. The optimum relative humidity for each commodity varies, but most all are in the range of 85 to 95 percent. A refrigerator car with bunker ice refrigeration can achieve and maintain temperature in the range of 34 to 45 F. for most commodities.

It is obvious, then, why ice refrigeration in railroad refrigerator cars has served so long and so well. Besides all other considerations it is admirably suited for the job. First, it will maintain very nearly the optimum temperature for most commodities; and, second, because the temperature differential between the commodity and the refrigerant is small, the humidity of the air is at the optimum range (85 to 95 percent) and the resulting loss of moisture by the commodity is small.

Problems With Ice Refrigeration

As ideal as ice refrigeration is for most fresh fruits and vegetables, there are of course problems. The temperature of the commodity when loaded directly into the car may range as high as 100 F. In addition to the sensible heat of the commodity, the vital heat or heat of respiration of the commodity contributes greatly to the refrigeration load. It would be practically impossible to incorporate into the car the refrigeration capacity to reduce, as rapidly as desirable, the temperature of such loads. Therefore auxiliary methods must be employed.

The commodity may of course be precooled before loading. After the car is loaded, however, the most common methods are trackside portable mechanical units; permanent brine and fan systems (of necessity located near or as part of an ice plant); both of which supplement the ice bunker refrigeration of the cars. A second method is the use of auxiliary fans or the car fans which, if operated continuously, serve to increase the refrigeration obtainable from the bunker ice.

Another method which has come into widespread use in recent years, and which is particularly advantageous for some commodities is top or body icing. In this method crushed ice, almost as fine as snow, is placed either in the container with the commodity or blown over the top of the load after the car is loaded. This serves not only to reduce the temperature rapidly but in the case of leafy and pulpy vegetables, the water from the melting ice helps maintain the turgidity and fresh appearance of the commodity. In some commodities however, the presence of water on the fruit is injurious and for that reason this method has only limited application.

Another method of reducing the temperature rapidly is the addition of small percentages of salt to the bunker ice. The practice of adding salt to increase the refrigeration capacity must be used with judgment as inexperience or improper handling may result in freezing damage to the commodity.

Standard refrigeration is the initial icing and reicing to bunkers capacity of the cars at regular intervals. These intervals are usually about 24 hours apart. The use of standard refrigeration on a properly precooled load will assure a commodity temperature in the 34 to 45 F. range during the entire transit history of the commodity. On those commodities that do not require these temperatures the number of icings are varied to meet the requirements. For example, lemons which require temperature in the 50 to 60 F. range, are sometimes shipped under a modified refrigeration of initial and one reicing in transit.

Perhaps the most critical of all commodities shipped by rail are frozen foods and frozen products. They are critical because their transit requirements are much more rigorous than any other commodity shipped and because their volume, while important, has been so small as to economically preclude special service and equipment. However this traffic is rapidly increasing and all carriers are giving special attention to service requirements. In spite of this, however, the railroads have handled this commodity successfully as evidenced by the growth and acceptance of frozen foods. Actually the claims paid on frozen foods by the railroads for improper refrigeration is much less than one percent of the value of the shipment. The carriers have successfully adapted the refrigerator car and service to this commodity by increasing the insulation thickness and by the addition of high percentages of salt to the bunker ice. While the use of heavier insulated cars is common wherever they are available, frozen foods are shipped successfully in the so-called standard refrigerator car with 3 to 3.5 inches of insulation.

Use of Ventilation and Heat

Of the approximately million and a half refrigerator car loads of perishables about one million are shipped under refrigeration while the remainder move about equally under ventilation and heat.

Commodities under ventilation move principally during mild seasons of the year. The temperature requirements are not narrow and the principal protection is against freezing. Standard ventilation simply requires that the hatches (or vents) be opened above an outside temperature of 32 F. and closed at 32 F. Special ventilation service allows the shipper to establish his own specifications as to the manipulation of the vents.

Heat for refrigerator cars is provided by small portable heaters installed in the ice bunkers or by heaters permanently installed underneath the car. It is doubtful that any one refrigerator car will average more than one load a year under heat. Therefore the larger investment, added weight and maintenance of the permanent units put them at an economic disadvantage and has resulted in the more widespread use of the portable units.

There are three basic heater services: (1) where the shipper allows the carrier to protect the shipment by any method or system he deems advisable, (2) where the shipper furnishes the heater and facilities and instructs the carrier as to their manipulation and operation and, (3) where the carrier furnishes the equipment but operates it according to the shippers instructions.

Portable heaters burn either charcoal or methanol as a fuel. Charcoal heaters, which were the first used, had no other control except to extinguish or light them at inspection points enroute, usually on the basis of outside temperature. Admittedly this control was rather crude but to a surprisingly degree successful. The desire for a closer control led to the development of thermostatically controlled heaters; particularly of the liquid fuel type. Of the liquid fuels, methanol has been found to be the most satisfactory. Charcoal heaters have been improved by a thermostatically controlled draft.

Research in Refrigerator Cars

Based on the knowledge and temperature specifications provided by the agricultural scientist, refrigerator car transportation research resolves itself into two rather broad phases: one, research on the effect of variations in refrigeration, heater or ventilation procedures, loading methods and containers, and methods of handling an ultimate market quality of the commodity; and research on the car itself including the refrigeration system, insulation, air circulation, construction, and the like.

Of the two, the second is perhaps more fundamental but is to a large

extent dependent on the first. As was pointed out previously, the refrigerator car because of its necessary simplicity is a fairly stable quantity. Therefore, before any change is made, a thorough investigation of the possibility of altering the auxiliary services or methods is tested. Only after these possibilities are exhausted is the refrigerator car itself considered.

Every refrigerator car loaded is in one opinion a test. However, perishable transportation research is done, of necessity, principally in the field—of necessity because of the hundreds of variables, which to date at least are impossible to duplicate in the laboratory.

One, for example, is the load itself. The properties of loads vary not only between kinds of commodities but between varieties and between maturities. We have been faced with the choice of duplicating all the variables in a full scale laboratory or with attempting to measure at least the more important variables in the field. Thus far it has seemed more practical, quicker, and less expensive to measure the variables in the field.

At the same time we have drawn heavily on the research done in the allied fields. We have attempted to build a moving "field laboratory" in which to test fully the experience of our friends and allies in the laboratory. If the idea or ideas seem successful, we then make hundreds of tests of the idea in regular service where we measure only the important variable, most often that of commodity temperature.

Instrumentation in "Field Laboratory"

The two phases of research require somewhat different equipment. In our "field laboratory" it may be necessary to measure temperature not only in the commodity but throughout the car superstructure. To account for possible variations in car construction, in loading method or refrigeration practice, we felt that 10 test cars might be required. At a minimum this would require some 500 different temperatures. In addition, the humidity, not only in the cars, but in the car superstructure would be important. In most cases a nearly continuous record was necessary.

The system devised for temperature was a series of remotely controlled impulse rotary switches spaced at 50-foot intervals and a master control cable which extended back into the business car. Each rotary switch had 23 contacts so that 23 thermocouple leads were available at each switch. Two such cables were built so that each of 10 cars would have 46 thermocouple leads, or if the number of cars were reduced the thermocouples per car could be increased. The master cable terminated in a selector control box located in the office car and the master thermocouple leads terminated in a direct reading Brown electronic indicating potentiometer.

The possibility of using a recording system was considered. However the number of readings involved and the necessity of taking readings from charts seemed more difficult than reading and logging the temperatures directly. A crew of four men operating both instruments could read all positions in about 10 minutes. The control system operated on 32 volts; the potentiometer on 110 volts. The low voltage was supplied by batteries; the 110 by a 2-kv diesel generator. The system has been in use continuously for two years and has given very satisfactory service.

The system for measuring humidity was not so elaborate. It consisted of 12 electric hygrometer elements on leads connected to a selector mounted on top of the car. Each element consists of seven wire-wound coated-plastic cylinders mounted in a plastic and screen cage. The coating absorbed moisture; the amount, depending on the relative humidity of the air, determined the conductivity of the coating. This conductivity (measured in microamps) by means of a calibration curve, could be translated to relative humidity.

Since the hygroscopicity of the cells depends to a certain extent on temperature, a second correction was necessary to obtain the true relative humidity. Except for the difficulty of translating a great many readings from microamps to relative humidity, and the fact that the readings could only be obtained when the train was stopped, the results obtained with this system were quite good. The authors understand that the American Instrument Co., the manufacturers of this equipment, have to a great extent, now overcome these objections.

A third element which we would like to measure is air velocity at various points in the cars. So far we have not been able to locate instruments of this type which would be satisfactory and which could be read remotely or while the train is moving. In lieu of actual measurements of air velocity we have used the relative temperatures in the car air and load to trace approximately the circulation.

Difficulties in Testing Procedures

It is obvious that the complexity of this equipment limits the number of cars and tests that can be run in any one season, and it is necessary, no matter how carefully we try to minimize or measure the variables, that enough tests be run to get the full range of conditions. In order to accomplish this a great number of unaccompanied test cars must be run. This may be accomplished either by installing recording thermometers in the car or by using thermocouple or resistance cables and taking readings with portable reading boxes at specified points enroute.

The advantage of recording thermometers is of course that they provide a continuous automatic record from origin to destination. Their disadvantage is that they are too expensive to use in the quantity we need since a separate instrument must be used for each temperature position. For this reason we decided that thermometers of the distant reading type would be needed.

Since only commodity temperatures are required it was felt that daily readings of temperature at specified points enroute would be sufficient, since the commodity temperature change would be small in this period of time. The principal disadvantage of this system was that the personnel at the check points would be largely untrained in the use of instruments. Therefore the equipment had to be simple, rugged, and relatively fool-proof.

Another requirement was that an estimated 100 cables would be required. Therefore the cables themselves would have to be inexpensive. This was the principle reason for turning to thermocouples rather than resistance type of equipment. They would also be more flexible in that, because of their cheapness, they could be discarded and replaced with other sizes, etc. without a great loss.

The eventual design consisted of a thermocouple harness with six thermocouple leads, door plate and six contact switches with connector. The reading box was a Wheelco potentiometer with an alternate air or ice cold junction. The thermocouple cables and certain modifications to the potentiometer were done by Sieco Inc. In order to protect the potentiometer against temperature extremes and rough handling, the instrument was cased in a wooden case insulated with about 2 inches of foam rubber. The scale was direct reading from −20 to 120° F with 1° divisions. In practice the air "cold junction" has not been too accurate and is seldom used.

Tests of Car Heaters With Instruments

An example of how these two types of temperature measuring equipment are used in a research program is found in the development of portable car heaters. After the war, manufacturers of several alcohol and thermostatically controlled charcoal heaters felt that their equipment had reached a stage of development where they could be used in service. The alcohol heaters were of several designs but were all thermostatically controlled. Both manual and thermostatic draft charcoal heaters were included.

It was decided that during the winters of 1946-47 and 47-48 the field laboratory equipment would be used to check closely on the performance of the heater. The thermostatic heater's advantages were that it would offer both better temperature control and would need no attention from origin to destination. By use of the field laboratory equipment these claims could be checked. During the winter of 48-49 the best of these heaters were checked in quantity during an entire season to get some idea of their reliability and performance in general service as compared to the older types already in service.

During the first two winters ten tests were run. The cars on each test were selected to be uniform in construction and performance. At the origin or loading point the cars were loaded and the particular heaters installed. During loading, thermocouples were placed in the commodity at representative and vulnerable points and throughout the air in the car interior as a check on the distribution of the heat and the circulation set up by the heater.

The heater was judged on its ability to protect the load against freezing, the narrowness of the temperature range in the commodity, and its operation as governed by the thermostat. The operation of the heater was checked by a thermocouple directly over the heater and by thermocouple at the temperature sensitive element of the thermostat. By comparing these two temperatures, we could determine how well the heater functioned. The air and commodity temperatures told the rest of the story.

Based on these results, the better heaters were purchased in limited quantities and put in regular service during 1948-49. During these tests the portable equipment was used exclusively. The procedure was basically this: Railroad employees at points along the line were furnished and instructed in the use of the portable potentiometers. The cars were loaded at the rate of 6 or 8 a day, the thermocouple cables installed, and the cars were moved in regular freight service to destination.

At each check point, temperature readings and a heater inspection were made. At destination a final inspection was made. In this way some 200 car records were obtained covering all types of heaters under a wide variety of weather conditions with most all types of equipment. The thermostatically controlled equipment showed some improvement, particularly in regard to the handling and operating features. However, the most surprising results were the good records obtained with the old equipment and old system.

Car Insulation Tests

Along with operational tests we have been concerned with the design of the refrigerator car itself, particularly with the amount of insulation necessary. The increased frozen food traffic had brought about insulation thicknesses up to 8 inches. It was questioned whether or not this thickness was necessary or even desirable. Super-insulated cars were limited and it has often been necessary to ship frozen commodities in cars with substantially less insulation. However, today, 22,000 super-insulated cars are available and the carlines are building more to handle increased frozen foods traffic. It was hoped that reasonable insulation thickness could be found, somewhat short of seven to eight-inches that could be incorporated into a so-called standard all-purpose car. In addition we needed some fundamental data on the heat transfer characteristics of the car, the total heat load, and the effect of some of the major variables encountered.

In the fall of 1946 six refrigerator cars were built to identical specifications except for the insulation thickness. Two cars had 3 inches of mass type insulation in the walls and 3.5 inches in the floor and roof—commonly called 3 to 3.5 inches of insulation. One car had 4 to 5 inches; one, 5 to 6; and two, 6 to 7 inches of insulation. Two of the six cars (one, 3 to 3.5 inches and one, 6 to 7 inches) had one layer of reflective paper in addition to the mass type insulation, in the sidewalls, ends and roof.

During the construction of the cars, thermocouples were placed in various sections of the cars. For example, a thermocouple was soldered to the underside of the steel roof; directly below it thermocouples were fastened on top below and between the layers of insulation; on both sides of the air spaces and on both sides of the inner plywood lining. A similar arrangement was used for representative sections of the sidewalls, ends and floors.

In addition, thermocouples were placed at what were suspected to be particularly vulnerable spots as far as heat transfer was concerned—for example, around the doors, hatches and at other structural members throughout the car. The purpose of this arrangement was to test the relative effectiveness of the various components and if possible to draw a heat balance.

The thermocouples were carried to the remote controlled rotary switch arrangement on the roof of the car. In addition to the thermocouples in the car superstructure, additional thermocouples were used for commodity, air and ice temperatures inside the car. During the construction of these cars, the electric hygrometers were installed in the car superstructure and in the car loading space.

It was desirable to test as many conditions of loading as possible and as many types of commodity as possible. To accomplish this five tests were planned: two with bunker ice with "warm loads" and with pre-cooled loads; one with body or top ice; and two with frozen foods. During each of these tests temperatures were recorded for each position every hour. Records of humidity were obtained every 2 to 4 hours. In addition a daily record of the refrigeration supplied, the outside air temperature and weather conditions were obtained.

On the basis of this data a heat balance was obtained showing that, depending on the commodity, from 25 to 60 percent of the total heat load was due to the sensible and vital heat of the commodity, and that additional insulation was effective in reducing only that 25 percent of the heat load attributable to the insulated area. As far as could be determined there was no particular temperature advantage obtained from increasing the insulation thickness beyond 3 to 4 inches.

The most important difference was in the ice meltage. It was evident that as long as the cars had normal movement enroute the refrigeration capacity of the cars was great enough to overcome the difference in heat loads. The value of reflective air spaces confirmed generally the published laboratory data.

Admittedly these results are only a step. However, they are being used today by the car builders in their attempt to improve the insulating efficiency of their cars.

Conclusions

Transportation of perishables, through the research and experience of many, has today achieved a degree of perfection that precludes great and sweeping improvements. Today we are looking for the small things in regard to each commodity that will increase its desirability in the mind of the consumer. In a sense we are retracing our steps and looking for the fundamentals.

We are trying to make our product, the refrigerator car, a less expensive, a more versatile and a more useful tool of a great industry. To do this we need more and better instruments both in the laboratory and in the field. In this we are handicapped by several things. One is that we require only a few instruments, the second is that they are special and must approach laboratory accuracy and yet be rugged enough for field use. We are in this sense a small and poor market for instruments. However, we will be bold and hope that when we call the instrument industry for help in this regard that we might have the benefit of its knowledge and experience.

Sturdy, dependable designs of instruments to accurately measure air circulation and humidity by remote control are required to enable us to progress and complete some of the research problems we have under way. We are hopeful that men specially trained in instrumentation may eventually develop suitable measuring devices.

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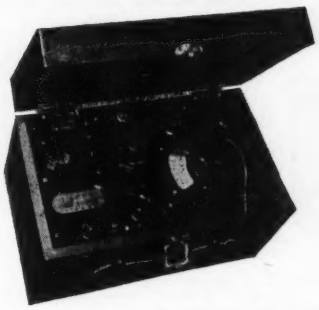

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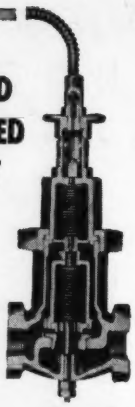

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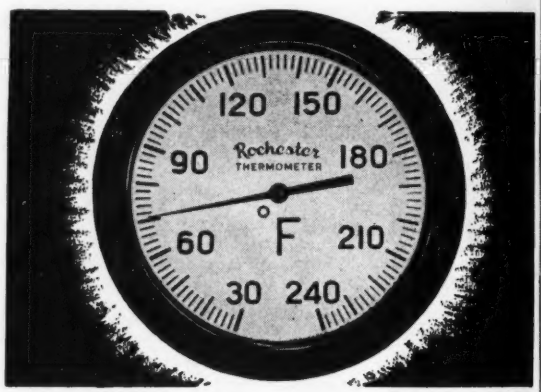

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Measurement *of* Flow *of* Fluids *through* Orifice Meters

with Particular Reference *to the* Measurements *of* Liquids *and* Steam

By WILLIAM L. COWAN, Union Oil Company

Editor's Note.—Because of its extreme length, Mr. Cowan's article has been divided into installments. The second installment will appear in the August 1951 issue of the *Journal*.

A GENERAL equation for the flow of any liquid through an orifice in a pipe can be expressed by the following formula,

$Q_f = 359.1\ d^2 K_o F_R \sqrt{h/w}$ Cu. ft./hr. at flow density, where

d = orifice diameter in inches

K_o = discharge coefficient for orifice, including the velocity of approach, for an infinite Reynolds Number flow condition

F_R = a correction to K_o for the actual Reynolds Number flow condition

h = differential pressure in inches of water at 60 F., representing the difference in pressure between the pressure at the upstream pressure tap and the pressure at the downstream pressure tap.

w = density of fluid at flow pressure and temperature expressed in pounds per cu. ft.

Note: Since for any one flow condition h varies with the type of pressure taps used, the values of K_o, F_R and h only apply to these values for the same type of pressure taps.

Also letting,

D = Internal diameter of meter tube

$\beta = d/D$

R = Reynolds Number at the orifice (upstream face)

$K_o = c_o(1/\sqrt{1-\beta^4})$ where

$(1/\sqrt{1-\beta^4}$ = velocity of approach correction

c_o = orifice discharge coefficient for infinite value of R

c = orifice discharge coefficient for actual value of R

$c = c_o F_R$

The specifications for the location of the pressure taps for the different pressure tap systems used to measure the differential pressure h are given as follows, the upstream distance being the distance upstream of the upstream face of orifice plate and the downstream distance being the distance downstream from the downstream face of the orifice plate.

Flange taps and pipe taps are the generally accepted standards used in the United States. The recommended and allowable ranges of orifice sizes for these two pressure tap systems are as follows, expressed in terms of beta.

	Recommended	*Allowable*
Flange taps	.15 to .70	.10 to .75
Pipe taps	.20 to .67	.15 to .70

Referring to the indicated pressure distribution curve in Fig. 1, it is seen that the pressure upstream of the orifice plate is approximately constant

	Upstream Distance	*Downstream Distance (Fixed)*	*β*	*Max.*	*Minimum*
Flange Taps	1 in.	1 in.			
Pipe Taps	2.5D	8D			
Corner Taps	0	0			
Throat Taps	1D	0.5D			
Vena Contracta (Approximate downstream distance is variable)	1D		0.75	0.27D	0.49D
			0.60	0.42D	0.70D
			0.45	0.47D	0.92D
			0.20	0.38D	1.32D

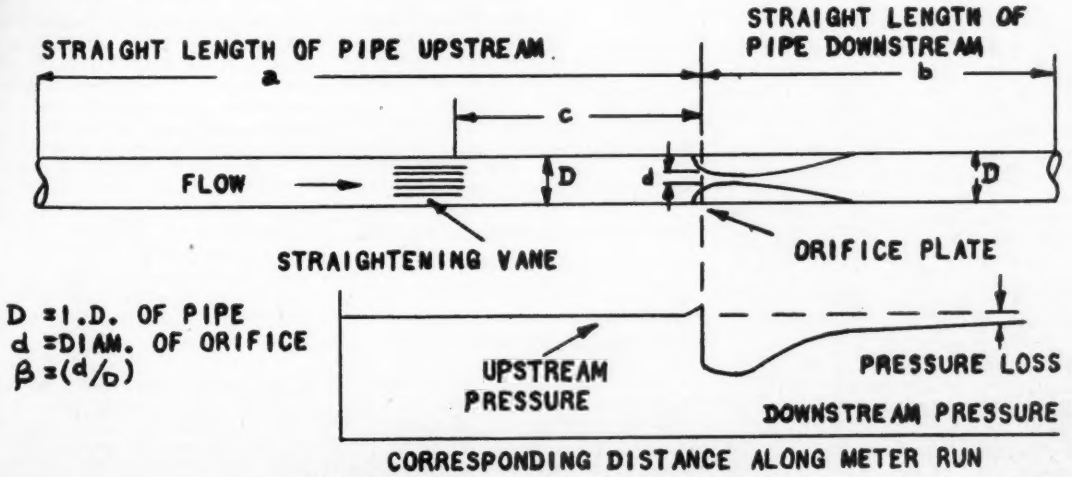

Fig. 1. General characteristics of flow through an orifice.

August Meeting: Thursday, the 16th, 1951, Rio Hondo Country Club, Downey, Calif. Dinner at 6:30, meeting at 8:00 P.M.

Feature: Ladies' Night. L. C. Musselman, speaker.

from a few pipe diameters upstream to a point close to the upstream face of the orifice where the pressure then builds up slightly. The pressure downstream of the orifice drops off perceptibly and reaches a minimum at the location of the vena contracta downstream tap and the pressure then gradually increases to some maximum value at a point some distance less than 8D downstream. The amount of pressure recovery increases as the beta ratio increases and is very small for beta ratios of 0.2 or lower.

From the value of the velocity of approach factor $= (1/\sqrt{1-\beta^4})$ it can be seen that this factor is small for low values of beta but is of importance for higher beta ratios as the velocity of the fluid through the pipe is an appreciable percentage of that passing through the orifice. The values of K_o, c_o and velocity of approach for various beta ratios in a 4.026-in. pipe for both flange and pipe taps are shown as follows:

	Flange Taps				*Pipe Taps*			
β	K_o	=	C_o	× (Vel. Appr.)	K_o	= C_o ×	(Vel. Appr.)
0.2	0.5949		0.5944	1.0008	0.6106	0.6101	1.0008
0.4	0.6082		0.6003	1.0131	0.6721	0.6634	1.0131
0.6	0.6487		0.6052	1.0719	0.8226	0.7674	1.0719
0.7	0.6916		0.6029	1.1472	0.9722	0.8475	1.1472
0.75	0.7253		0.5997	1.2095			

To make a comparison of the differentials obtained by pipe taps and flange taps, and assuming that pipe taps represent the overall pressure drop across the meter installation and using subscripts P for pipe taps and F for flange taps and assuming the same d, w and flow rate in a 4.026-in. pipe and neglecting any other small variations, then

$$Q_f = (\text{Constant } A) \times K_{oF}\sqrt{h_F} = A \times K_{oP}\sqrt{h_P} \quad \text{or}$$

$$K_{oF}\sqrt{h_F} = K_{oP}\sqrt{h_P}$$

	K_O Values		Comparison Pipe Taps to Flange Taps		Comparison Flange Taps to Pipe Taps				
								% of h_F	
β	K_{OP}	K_{OF}	K_{OP}/K_{OF}	h_P/h_F	K_{OF}/K_{OP}	$\sqrt{h_F/h_P}$	h_F/h_P	Recov.	Lost
0.1	0.6011	0.5955	1.0094	0.9815	0.9907	1.0094	1.0189	1.85	98.15
0.4	0.6721	0.6082	1.1051	0.8188	0.9049	1.1051	1.2212	18.11	81.89
0.5	0.7303	0.6230	1.1722	0.7278	0.8531	1.1722	1.3741	27.23	72.77
0.6	0.8226	0.6487	1.2681	0.6219	0.7886	1.2681	1.6081	37.81	62.19
0.7	0.9722	0.6916	1.4057	0.5061	0.7114	1.4057	1.9760	49.39	50.61

Since h_p is the total pressure lost, the flange tap differential recovered $= (h_F - h_P)$ and the percent of flange tap differential pressure recovered $= 100(h_F - h_P)/h_F$ or letting $r = h_F/h_P$ and $h_P = h_F/r$ the percent differential recovered $= 100[1-(1/r)]$

As can be seen from the general formula, to obtain the same volume rate of flow of two different fluids through a given orifice in a pipe and with the same pressure taps, a higher differential will be required to move the fluid of the greatest density.

The value of F_R for infinite or very high values of R will equal 1.0000 as $c = c_o$. In general, the coefficient (C) and therefore F_R for any given orifice in a pipe will be increased as the value of R is decreased. The first noticeable effect of lowering R is in the retardation of the motion of the fluid over the upstream face of the orifice plate toward the orifice and around the orifice edge. The flow begins to creep around the corner of the orifice more slowly and the centrifugal force urging the fluid towards the jet downstream of the orifice is diminished. Consequently there is less jet contraction and the cross-section of the jet is increased, causing the discharge coefficient C to increase. The above effects of continually lowering the value of R will cause the coefficient (C) to further increase until some point is reached where the increased differential force required to move the fluid through the meter begins to offset the increase in coefficient caused by the lessening of the contraction of the jet. The R value at the point where this condition takes place varies with beta, being about 200 for beta = 0.2 and about 1000 for beta = 0.75. Further lowering of R beyond these values will cause the discharge coefficient to begin to decrease more and more rapidly. The F_R values for the same value of R between R values of 100 to 10,000 will be greater for the higher beta ratio orifices.

In order that discharge coefficients and factors will correspond to established published test values it is essential that orifice meter installations be properly designed according to recommended specifications which have been summarized later.

In the measurement of some fluids, it is necessary to use some liquid sealing fluid between the pressure taps and recording gages. When mercury gages are used to record the differential pressure and the weight of the fluid over the mercury is appreciable compared to that of the mercury, a manometer correction factor will be required.

In order to simplify orifice meter flow calculations used in the measurement of gases, liquids and steam, special flow formulas have been developed for each of these fluids to give flow results in the units most commonly required.

General Requirements for Good Measurement

Fluid being measured should be of relatively constant composition. Its characteristics must be known so that its density can be accurately determined for various flow conditions.

For accurate liquid measurement the pressure of the liquid should be high enough to prevent vaporization of liquid or other dissolved gases.

For steam or gas measurement the meter run and flow lines should be free from liquid accumulations.

Flow for good measurement should be such that the pressure and differential record can be clearly read. Where flow is extremely variable, it can only be recorded by spreading out the flow records by use of charts revolving at shorter periods than commonly used.

Differential and pressure recordings, when possible, should be of such magnitude that they will be registered from 5 to 10 units on a square root chart or the equivalent of these square root chart readings when other forms of charts are used. Changes in orifice size or of the ranges of pressure spring or differential gage offer means of adjusting the position of these records on the recording chart.

Flow should be in turbulent flow region for good measurement.

Sufficient lengths of straight pipe both upstream and downstream from the orifice plate must be installed to prevent any distortion of flow both at the orifice plate and at the pressure taps. The lengths of straight pipe required vary with the orifice to pipe ratio, beta, the lengths of straight pipe required increasing as the value of this ratio increases. Orifice meter installations should however be designed so that correct measurement can be obtained with any orifice which may be used. The lengths of straight pipe used should therefore be designed for the maximum allowable orifice to pipe diameter ratio. Specifications for the minimum lengths of these meter runs based on the use of the maximum allowable orifice to pipe diameter ratio as well as other general orifice meter installation specifications are furnished below.

Flange taps are recommended in all instances and particularly in the measurement of fluids through vertical meter runs.

In the measurement of fluids no pulsation of fluid at the orifice meter should be present. It is generally impossible to accurately measure fluids by an orifice meter when pulsation is present.

In the handling of gases the most satisfactory method of suppressing pulsation at the orifice meter is to introduce a large reservoir or a pressure drop or a combination of both between the orifice meter and the source of pulsation. In some instances errors in measurement caused by pulsation can be minimized by the use of a meter run which will permit the use of a high beta ratio orifice and the carrying of a high differential pressure. By locating orifice meters at a considerable distance from the source of pulsation, the volume of the pipe and the resistance to flow through the pipe are utilized to suppress pulsation.

A new patented device for eliminating pulsation in gas flow lines has been developed which has apparently proven fairly successful. It must however be designed for each individual flow condition.

When pulsation in a flow line exists,

the retardation of the movement of the mercury in the recording gage either by the use of bushings in the mercury column or by cracking valves on the lead lines to the gage, will not correct for any errors caused by pulsation in the flow line.

Orifice Meter Installation Specifications (Ref. Fig. 1)

Specifications for Diam. of Pressure Tap Openings at Inside of Pipe

Openings should not be less than 0.25 in. in any case.

Openings for 2- to 4-in. pipe should not be greater than (⅛)D.

Openings for 4- to 8-in. pipe should not be greater than 0.5 in.

Openings for 8-in. and larger pipe should not be greater than (1/16)D.

Edges of tap holes should be free from burrs and slightly rounded off on inside of pipe section.

Gage piping should not be less than 0.25 in. nor more than 0.75 in.

Straightening Vanes

The greatest inside cross section of any passage through a straightening vane should not be greater than (¼)D.

The length of the vane should be at least 10 times the greatest inside cross section of any passage through the vane. Vanes should be firmly constructed and securely fastened in place.

Thermometer Wells & Sampling Connections

Thermometer wells and sampling connections should be placed downstream from orifices at least not closer than "minimum downstream specified straight length of pipe." If straightening vanes are used, the thermometer well or sampling connection can be installed in the upstream meter run one pipe diameter or more upstream of straightening vane. Thermometer wells should be inserted in such a manner that true flow temperature is obtained. Sampling connections should be of center line type.

In measurement of moist steam, sampling devices should be installed for determining steam quality if accurate measurement is required.

The sections of pipe used for meter tubes, that is the pipe sections adjacent to the orifice flange or orifice fitting shall be as nearly cylindrical, smooth and free from blisters and scale as can be commercially obtained. The method of determining the I.D. of the pipe and also the allowable tolerance between the actual I.D. of the pipe and the I.D. of the pipe used in the computation of orifice meter coefficients are given above.

Pipes having the following scheduled (published) I.D. have been chosen as standard for use in orifice meter runs: 2.067, 3.068, 4.026, 6.065, 8.071, 10.19, 12.09, 15.25, and 19.18 in. Orifice meter coefficients have been established for such pipe, based on these diameters. Pipes of other scheduled I.D. may, however, be used and coefficients can be established for orifices used in such pipe. In some cases, the actual I.D. of the upstream pipe section is used in the calculation of coefficients, and in such instances this average diameter shall be obtained from the averages of measurements of the I.D. as above specified.

The allowable tolerance in the bore of orifice fittings of the Robinson, Daniel, etc. types have not been definitely established but the allowable tolerance recommended is 0.2 percent of the I.D. of pipe used in the calculation of the orifice meter coefficients.

Pipe Flanges and Gaskets

Recesses should be avoided on the inner surface of the pipe between the end of pipe and face of flange on pipe flanges close to the orifice plate or the orifice fitting, however a recess 0.25 in. long as measured parallel to the axis of the pipe is allowable.

Pipe flange and orifice fitting flange and gasket should be dowelled in such a manner that I.D. of pipe is centered to I.D. of orifice fitting and so that the gasket will not protrude into the bore of the pipe. The I.D. of the gasket should be slightly larger than I.D. of pipe.

MINIMUM LENGTHS OF STRAIGHT PIPE REQUIRED FOR MAXIMUM ALLOWABLE BETA RATIO

Tabulated Lengths in Terms of Pipe Diam. D (See Fig. 1)	Flange Taps for $\beta = 0.75$					Pipe Taps for $\beta = 0.70$				
	No Vane		With Vane			No Vane		With Vane		
Fittings Upstream of Meter	a	b	a	b	c	a	b	a	b	c
I. One Ell or Tee Ahead of Orifice Meter Run	16.7	4.4	(Not required)			16.0	12.3	(Not required)		
II. Reducer Ahead of Orifice Meter Run	13.7	4.4	(See Note)			14.3	12.3	(See Note)		
III. Two Ells or Bends Ahead of Orifice Meter Run. (Bends in same Plane)	22.0	4.4	14.0	4.4	7.3	21.0	12.3	14.1	12.3	8.7
IV. Two Ells or Bends Ahead of Orifice Meter Run. (Bends not in same Plane)	35.0	4.4	15.0	4.4	7.3	33.0	12.3	15.5	12.3	8.7
V. Two Ells or Bends Ahead of Orifice Meter Run not in same Plane which are preceded by another Ell or Bend not in same Plane as Middle Ell	70.0	4.4	15.0	4.4	7.3	66.0	12.3	15.5	12.3	8.7
VI. Valve, Regulator or Control Valve Upstream of Orifice Meter Run	44.5	4.4	17.0	4.4	7.3	41.0	12.3	17.4	12.3	8.7

Note: If straightening vanes are desired in Case II, reducer ahead of orifice, vanes should be placed in piping directly upstream of reducer and not in the meter run. (See S.C.M.A. Data Sheet No. 181 for dimensions in feet and inches for various pipes.)

ALLOWABLE TOLERANCES IN I.D. OF PIPE USED FOR ORIFICE METER RUNS FROM THE I. D. OF PIPE USED IN THE COMPUTATION OF THE ORIFICE METER COEFFICIENT, BASED ON THE USE OF AN ORIFICE HAVING THE MAXIMUM ALLOWABLE BETA RATIO

Type of Orifice Fitting used	Flange Taps		Pipe Taps	
	Upstream	Downstream	Upstream	Downstream
When using plain flange orifice fittings ...	0.50% D	1.00% D	0.2% D	0.4%D
When using Robinson, Daniel or Commercial types of orifice fittings	0.25% D	0.50% D	0.2% D	0.4%D

Note: I.D. of pipe should be determined at cross sections of 1 in. from face of flange and at other cross sections up to one pipe diameter from face of flange. Measurements of I.D. of pipe should be taken over three and preferably five or six diameters. The difference between the maximum and minimum observed diameters (i.e. the out of roundness) should not exceed the tolerance specified above.

Orifice Plate Specifications

Pipe Sizes	*Allowable Plate Thickness*
2- up to 4-in. pipe....	Not less than 1/16 nor greater than ⅛ in.
4- up to 16-in. pipe....	Not less than ⅛ nor greater than ¼ in.
16-in. and larger pipe...	May exceed ¼ but not greater than ⅜ in.

Orifice Plate Thickness at Orifice Edge

The thickness of the orifice plate at the edge of the orifice shall not exceed (1/30)D, and preferably (1/50)D, or (⅛)d, or (⅛)(D-d), the minimum of the above requirements governing in all cases. Beveling of the orifice plate at the orifice with a 45-deg. bevel on the downstream side is often required to fulfill the above specifications for orifice plates. (See S.C.M.A. Data Sheet 188)

Orifice plates should not deviate from flatness more than 0.01 in. per inch of pipe radius and plate must be placed perpendicular to axis of pipe.

The upstream edge of an orifice shall be square and sharp and not appreciably reflect a beam of light when viewed without magnification and face of plate should be kept clean at all times.

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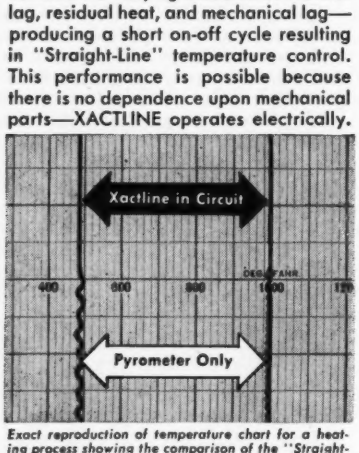

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Manufacturers' New Literature

In this department we report new literature pertaining to Instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 825.

Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

T-475 Recording Voltmeters and Ammeters. Bulletin E1111 describes maker's "Series 500" recording voltmeters, ammeters, and accessories.—The Bristol Co., Waterbury 20, Conn.

T-476 Oscillographs. Vol. 1, No. 1 issue of house organ "Hathaway Engineering News," features: New Highs in Frequency Response with Recording CRO, New Type S8 Oscillograph, Electromagnetic Dynamometer for Tension Measurement, and Moments of Inertia of Simple Elements.—Hathaway Instrument Co., 1315 South Clarkson St., Denver 10, Colo.

T-477 Oscilloscope. Data sheet describes maker's Model T-601-B 5-inch oscilloscope.—Television Equipment Corp., 238 William St., New York 38, N. Y.

T-478 Testing Instruments. Buyer's Guide GEA-5469 describes maker's line of electrical testing instruments, including hook-on volt-ammeter and wattmeter and power-factor meter, portable recorders, voltmeters, ammeters, phase-sequence indicator, and instruments for measuring magnetic fields, welding cycles, resistance, speed, viscosity, roughness, and time intervals.—Apparatus Dept., General Electric, Schenectady, N. Y.

T-479 Electronic Equipment. Catalog describes maker's electronic laboratory instruments, including all-band spectrum analyzer, microwave signal sources, video amplifier, and laboratory power supplies.—Polarad Electronics Corp., 100 Metropolitan Ave., Brooklyn 11, N. Y.

T-480 X-Y Recorder. Bulletin 330 describes "Model MD-2" recorder which plots any two variables that can actuate the movable cores of minature transformers ("Microformers").—Baldwin-Lima-Hamilton Corp., Phila. 42, Penna.

T-481 Function Plotter. Instrumentation Data Sheet 10.0-5 describes maker's "ElectroniK" function plotter. Other instruments described briefly.—Station 40, Brown Instrument Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Phila. 44, Penna.

T-482 Measuring Independent Variables. Instrumentation Data Sheet No. 10.0-6 describes how the "Duplex Electronik" strip-chart recorder provides simultaneous measurement of two independent variables.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Phila. 44, Penna.

T-483 Analog Computer. "Catalog and Manual" describes origin, development, applicability, each component, operating procedures, and bibliography for makers "GAP/R" electronic analog computers.—Geo. A. Philbrick Researchers, Inc., 230 Congress St., Boston 10, Mass.

T-484 Strip Chart Recorders. Condensed catalog, Bulletin Z6700, describes maker's strip-chart recorders, indicating controllers, program controller, pyrometers, resistance thermometers, combustion safeguards, potentiometers, "Limitrol" automatic temperature shut-offs, automatic positioning controls and pyrometer accessories.—Wheelco Instruments Co., 847 W. Harrison St., Chicago 7, Ill.

T-485 Recorder Amplifier. Bulletin 332 describes maker's direct-writing recorder-amplifier assembly designed for inkless recording of electrical unbalance of a resistance bridge when using strain-sensitive elements. Includes operation and accessories.—Baldwin-Lima-Hamilton Corp., Phila. 42, Penna.

T-486 R-F. Power. Vol. 2 No. 7-8 issue of house organ "hp Journal" features article "Power Measurement from 10 to 12,400 Megacycles." Describes use of bolometer mounts, power meters, attenuators, and terminations.—Hewlett-Packard Co., 395 Page Mill Road, Palo Alto, Calif.

T-487 Testing Machine For Accelerommeters. Bulletin describes "G Accelerator" centrifuge for subjecting instruments or components to steady or variable accelerations.—Genisco Inc., 2233 Federal Ave., Los Angeles, Calif.

T-488 Oxygen Recorder. Bulletin 51-829 describes principles, construction, and operation of maker's "Magnotherm" oxygen recorder. Maker's line of combustion and industrial instruments and controls are listed and classified.—The Hays Corp., Michigan City, Ind.

T-489 Combustion Meters. Bulletin 51-553 describes application and principle of maker's CO_2 recorders. Models are listed for various services.—The Hays Corp., Michigan City, Ind.

T-490 Combustion Instruments. Bulletin 51-949 describes maker's line of combustion and industrial instruments and controls. Gives picture, brief description, and bulletin for O_2 recorder, combustion meter, boiler efficiency meter, CO_2 recorder, flowmeters and gages, and draft gages.—The Hays Corp., Michigan City, Ind.

T-491 Production Counter. Folder describes maker's line of stamping press and production counters. Includes parts list.—R. E. Hart Manufacturing Co., 635 South Main St., Ann Arbor, Mich.

T-492 Scales. Catalog contains maker's bulletins describing dynamometer scales for measuring tension and force, push-pull gages for tensions and pressures, scales and test gages, force-measuring devices, brush-tension gages, platform scales, tensiometers, torque testers, consistometers for hardness or consistency of bituminous materials, and "Telepoise" conveyor scale.—John Chatillon & Sons, 85-93 Cliff St., New York 7, N. Y.

T-493 Level Indicator. Bulletin describes maker's electronic "Bin Level Indicator" which indicates when bins or tanks are full or empty, and electronic "Feeder Control" which synchronizes feeder and grinder motors.—Mosher Electronic Controls, 25 Boston Post Rd., Larchmont, N. Y.

T-494 Torquemeter. Bulletin 328 describes principles, specifications, and dial graduations for maker's "SR-4" torquemeters, which use resistance-wire strain gages.—Baldwin-Lima-Hamilton Corp., Testing Equipment Dep't., Phila. 42, Penna.

T-495 Pyrometers. Folder N-33-640 (1) describes immersion thermocouple and immersion "Rayotube" equipment for molten steel temperature measurement. Cites advantages which aid in determining choice. Complete specifications for each system.—Leeds & Northrup Co., 4934 Stenton Ave., Phila. 44, Penna.

T-496 Turbidimeter. Catalog No. 8000-A describes new instrument for measuring water turbidity, sulfate determination, and suspended matter and colloids. Includes operating principles and prices of calibrated and uncalibrated models.—Hellige, Inc., 3718 Northern Blvd., Long Island City 1, N. Y.

T-497 Glossmeters and Reflectometer. Bulletin describes 1951 models of maker's glossmeters and 45°0° reflectometer. Describes operation and various methods, including 60° gloss, 45°0° reflectance, 75° gloss, 85° sheen, 45° gloss, and 20° high-gloss.—Henry A. Gardner Laboratory, Inc., 4723 Elm St., Bethesda, Md.

T-498 Vacuum Gages. Data sheets describe (1) "Thermocouple Gauge Type TG-02," (2) "Philips Gauge Type PHG-1," (3) "Ionization Gauge Control Circuit Type DPA-38," and (4) "Ionization Gauge Tube Type VG-1A." Includes operation and specifications.—Distillation Products Industries, Division of Eastman Kodak Co., Rochester 3, N. Y.

T-499 pH Meter. Bulletin describes maker's pocket-size analytical pH meter with probe unit, buffer, and Kcl solutions.—Analytical Measurements, Inc., 585 Main St., Chatham, N. J.

T-500 Measuring Microscopes. 24-page Bulletin 161-48 illustrates and describes maker's measuring microscopes for laboratory and shop; discusses selection and use, elementary topics, construction and accessories.—Gaertner Scientific Corp., 1201 Wrightwood Ave., Chicago 14, Ill.

T-501 Viscometers. "Brookfield Viscosity Packet" is group of literature, consisting of catalog, Data Sheet 034 for UL Adapter, 1951 price lists, "What Users Say" brochure, and pertinent reprints on viscosity.—Brookfield Engineering Laboratories, Inc., Porter St., Staughton, Mass.

T-502 Aircraft Pressurization. Bul-

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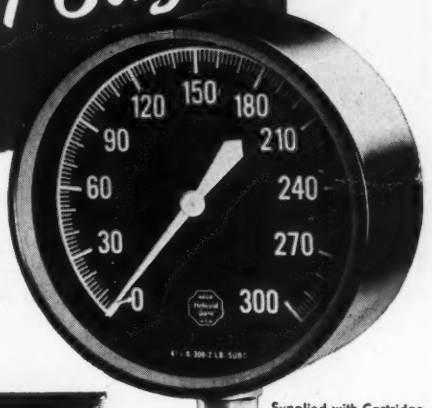

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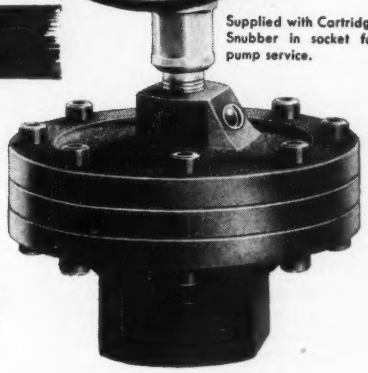

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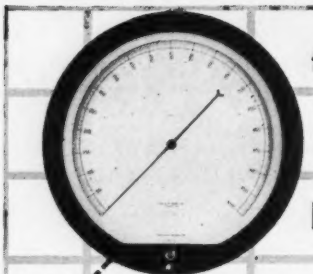

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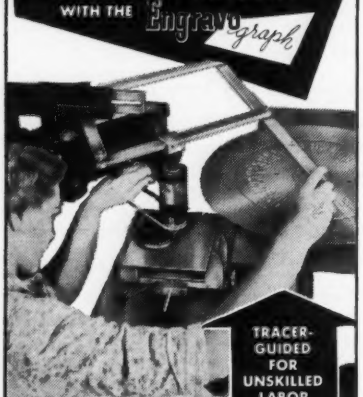

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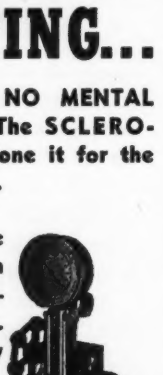

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NEW LITERATURE

letin 300 describes maker's aviation pumps, pressurization units, and heat dissipating units. Includes engineering data and specifications.—Eastern Industries, Inc., 296 Elm St., New Haven 6, Conn.

T-503 Kymograph. 20-page house organ, No. 51-3-42 issue of "The Burrell Announcer" features articles "Rubber and the Manufacture of Rubber Tubing" and the "Walton-Bird" kymograph; illustrates and describes numerous laboratory instruments.—Burrell Corp., 2223 Fifth Ave., Pittsburgh 19, Penna.

T-504 Recorders, Controllers. 12-page Bulletin 231-A illustrates and describes maker's electronic-type instruments for temperature, flow, pressure and other factors; discusses features and measuring circuits.—Bailey Meter Co., 1050 Ivanhoe Road, Cleveland 10, Ohio.

T-505 Potentiometer Controller. Specification Sheet No. 175 gives specifications of new "Electronik" Strip-Chart Pneumatic Control Potentiometer. Includes features and dimensions. —Minneapolis-Honeywell Regulator Co., Industrial Div., Phila. 44, Penna.

T-506 Industrial Controllers. Catalog 8304 describes maker's electric and pneumatic automatic control systems and accessories for temperature, pressure, flow, liquid level, and humidity. Includes definition of control terms and detailed specifications of systems and components.—Minneapolis-Honeywell Regulator Co., Industrial Div., Phila. 44, Penna.

T-507 Air-fuel Ratio Controller. Vol. 11 No. 1 issue of house organ "Modern Precision" features maker's air-fuel ratio controller applicable to oil or gas firing. Other articles are on applications of maker's products to temperature control of ovens, weighing of foundry sand, pH control, etc.—Leeds & Northrup Co., 4907 Stenton Ave., Phila. 44, Penna.

T-508 Variac Speed Control. Vol. XXV No. 12 issue of house organ "General Radio Experimenter" features article on an improved speed control for motors. Also describes "Type 71-A Variac Transformer".—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

T-509 Feed Regulator. Technical Bulletin No. 7 describes feed regulator useful in hammer mills, extractors, etc., which can be applied to any type of

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feeder. Includes installation and operation.—Mosher Electronic Controls, 25 Boston Post Rd., Larchmont, N. Y.

T-510 Pumping-station Pressure Control. Instrumentation Data Sheet No. 7.2-1 describes use of control system which protects pump and crude-oil line by limiting both suction and discharge pressures.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Phila. 44, Penna.

T-511 Combustion Safeguards. Catalog 9601 titled "Protectoglo Combustion Safeguard for Industrial Gas-fired and Oil-fired Burners" includes information on the "flame-rectification principle," descriptions of the system components, installation drawings, bills of material, and comprehensive information on 24 safeguard systems.—Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne and Windrim Aves., Phila. 44, Penna.

T-512 Controlling Potentiometers. Catalog 15-15 describes maker's "ElectroniK" electric control potentiometers for both contact and proportional control. Includes application data and accessories.—Station 40, Industrial Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Phila. 44, Penna.

T-513 Liquid Level Controllers. Bulletin No. 1110 describes "Autocon Multi-Pump Tanktrols" for maintaining liquid levels in elevated tank systems. —Automatic Control Co., St. Paul 4, Minn.

T-514 Controllers, Pyrometers. Catalog contains maker's bulletins describing "SIM-PLY-TROL" contact-type automatic controllers, pyrometers, controlling pyrometers, and electrical instruments.—Assembly Products, Inc., Chagrin Falls, Ohio.

T-515 Motor Control Equipment. Catalog, Fifth Edition, describes d-c. apparatus (relays, contactors, switches, and starters), drum switches, rheostat speed regulators, a-c. manual starting switches, a-c. magnetic switches, push-button limit switches, accessories (trip relays, overload relays, pressure switches and controls, timing relays, and solenoids), and synchronous starter. —Allen-Bradley Co., 136 W. Greenfield Ave., Milwaukee 4, Wis.

T-516 Automatic Timers. Catalog T-17 describes maker's new dual-speed electric 85-minute interval timer, 4-hour timers, 1-hour timers, and other time controls.—International Register Co., 2614 W. Washington Blvd., Chicago 12, Ill.

T-517 Voltage Regulators. Bulletin S351 describes principles, specifications, and engineering data on maker's line of "Type IE" (instantaneous electric) and "Type EM" (electromechanical) automatic voltage regulators.—The Superior Electric Co., Bristol, Conn.

T-518 Laboratory Equipment. Bulletin 515 describes portable autoclaves, midget refrigerator, vacuum control manostats, motor-driven blender, "Rotameter" flowmeter, flash evaporator for heat sensitive solutions, stainless steel filters, stopwatches, stainless-steel needle valves, non-corrosive pumps, and laboratory sundries.—Andrew Technical Service, 3805 N. Clark St., Chicago 13, Ill.

T-519 Diffusion Pumps. Data sheet describes physical and operating data of new line of oil diffusion pumps

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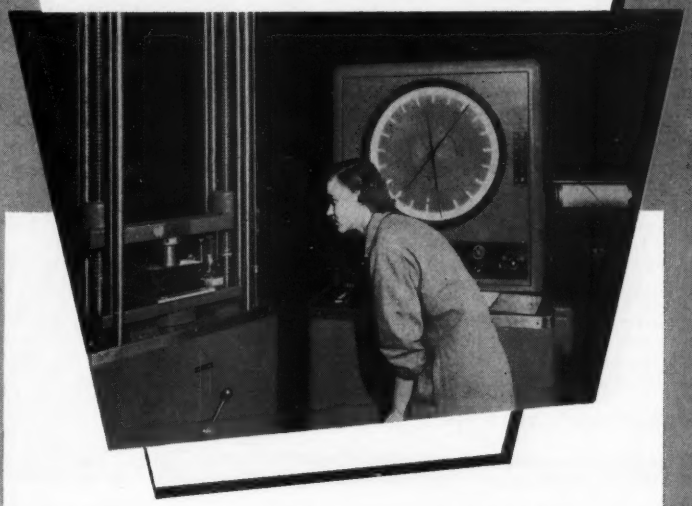

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for high-vacuum evaporators.—Optical Film Engineering Co., 2733 North Sixth St., Phila. 33, Penna.

T-520 Laboratory Equipment. Vol. 1 No. 3 issue of house organ "The Welch Physics Digest," features digests on subjects of wave polarization, NBS information, voicing organ pipes, inductive teaching, and man's use of energy. Includes maker's products for classroom and laboratory.—W. M. Welch Scientific Co., 1515 Sedgwick St., Chicago 10, Ill.

T-521 Rod Clamps. Data sheet describes maker's clamps for rod to rod, rod to sheet, pipe supports, extension rod clamps, and round rod to square clamps.—Chandler & Stedman, 398 Newton St., Waltham 54, Mass.

T-522 Glass Volumetric Apparatus. Booklet is titled "The Care and Handling of Glass Volumetric Apparatus." Includes systems of weights and measures, standard temperature, cleaning methods, and delivery characteristics of burettes and pipettes.—Kimble Glass Co., Division of Owens-Illinois Glass Co., Vineland, N. J.

T-523 Thermal Conductivity Cells. Folder describes installation and operation of maker's thermal conductivity cells. Includes typical circuit, calibration curves, and filament specifications. —Gow-Mac Instrument Co., 22 Lawrence St., Newark 5, N. J.

T-524 Digital Converter. Technical Data Sheet No. 10.0 describes maker's "Analog Digital Converter," which converts mechanical position into electrical contact settings. Includes circuit diagram.—Genisco, Inc., 2233 Federal Ave., Los Angeles, Calif.

T-525 Power Supplies. Bulletin describes maker's a-c. and d-c. power-supply units for laboratory, shop, and field. —Arthur E. Booth Co., 4124 Beverly Blvd., Los Angeles 4, Calif.

T-526 Vacuum Thermocouples. Vol. 18 No. 4 issue of house organ "Electrical Measurements" features article on vacuum thermocouples. Describes maker's thermocouple millivoltmeters, audio-frequency milliammeters, and radio-frequency milliammeters.—Sensitive Research Instrument Corp., 9-11 Elm St., Mt. Vernon, N. Y.

T-527 Thermocouples and Accessories. Bulletin 330-D describes maker's rare-metal and base-metal thermoelements, insulators, protection tubes, terminal heads, and accessories. Includes methods of reclaiming.—Charles Engelhard, Inc., 850 Passaic Ave., East Newark, N. J.

T-528 Load Cells. Bulletin has price list of SR-4 load- and pressure-sensitive devices.—Baldwin-Lima-Hamilton Corp., Phila. 42, Penna.

T-529 Strain Gage. Bulletin 322 describes new SR-4 "Post-Yield" resistance-wire strain gage suitable for strains up to 10 percent.—Baldwin-Lima-Hamilton Corp., Phila. 42, Penna.

T-530 Electrical and Electronic Components. House organ "What's New at Alden's" describes indicator light, fuseholder, sockets, connectors, tube caps, analyzer kit, test prods, and other components.—Alden Products Co., 117 North Main St., Brockton 64, Mass.

T-531 Electronic Components. Price list "Spring Mailer" lists tubes, capaci-

tors, and volume control in stock.—Sun Radio & Electronics Co., Inc., 122-124 Duane St., New York 7, N. Y.

T-532 Precision VDR and Dial. Bulletin describes "Micropot" precision ten-turn voltage-dividing resistor, and "Microdial" ten-turn counting dial with index accuracy of 1 part in 1,000.—Borg Equipment Division, The George W. Borg Corp., Delavan, Wis.

T-533 Precision Voltage-dividing Resistors. Folder has reference data chart of electrical characteristics and physical dimensions of maker's line of precision VDR's. Includes construction features and stock units.—The Helipot Corp., 912 Meridian St., South Pasadena, Calif.

T-534 Transformers. Brochure describes the research, design, and production facilities. Maker's products—constant-voltage transformers, lighting transformers, and air-cooled transformers—are shown.—Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill.

T-535 Instrument Transformers. 1951 Instrument Transformer Buyer's Guide, GEA-4626, supplies buying information and technical data on indoor and outdoor potential transformers, current transformers, metering outfits, potential and current transformers. Ratio and phase-angle tests, and tables covering mechanical and thermal limits are included.—General Electric Co., Schenectady 5, N. Y.

T-536 Pulse Transformer. Binder describes maker's miniature pulse transformer Model MPT 101. Includes pulse-forming blocking-oscillator circuit and waveshape data.—PCA Electronics, Inc., 6368 DeLongpre Ave., Hollywood 28, Calif.

T-537 Transformer Catalog. Catalog No. NE-551 describes characteristics of maker's power and audio chokes, filters, modulation reactors, and transformers.—Chicago Transformer Division, Essex Wire Corp., 3501 Addison St., Chicago 18, Ill.

T-538 Resistors. Bulletin B-1 describes maker's line of fixed composition resistors with ratings of ⅓, ½, 1, and 2 watts. Includes characteristics, specifications, coefficients, etc., by charts.—International Resistance Co., 401 N. Broad St., Phila. 8, Penna.

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T-539 Metallized Paper Capacitors. Bulletin NB144 describes maker's "Metapup" hermetically sealed capacitors with one-piece metal tubular case. Includes dimensions and ratings.—Cornell-Dubilier Electric Corp., South Plainfield, N. J.

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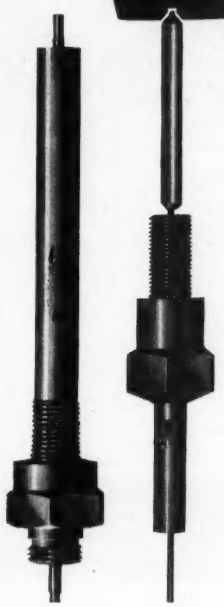

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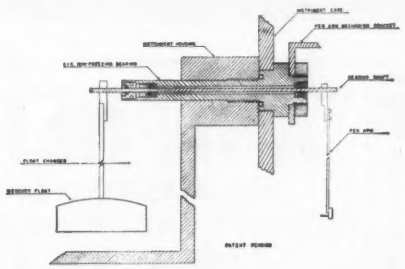

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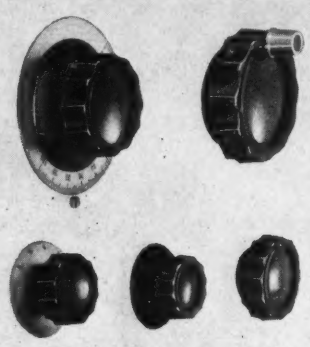

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T-541 Metallized Paper Capacitors. Bulletin NB142 describes maker's "Pup" metallized paper capacitors in paper tubes.—Cornell-Dubilier Electric Corp., South Plainfield, N. J.

T-542 Ceramic Capacitors, Engineering Bulletin No. 603 describes new line of metal-cup ceramic capacitors, including construction, dimensions, and temperature coefficients.—Herlec Corporation, 422 North 5th St., Milwaukee 3, Wis.

T-543 Diaphragm Motor Valves. Specification Sheet No. 416-1 covers theory, applications, and engineering data on maker's models of 3-way control valves. Includes data on materials, body pressure ratings, maximum differential pressure or drop, and flow-lift characteristic.—Station 40, Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves. Phila. 44, Penna.

T-544 Oil-operated Valve. Vol. 3 No. 1 issue of house organ "Engineering News" has articles on oil-operated throttle-trip valve, "Rotameters," spray nozzle systems, steam-jacketed herringbone gear pump, and plane-refueling system.—Schutte and Koerting Co., 18 State Road, Cornwells Heights, Bucks Co., Penna.

T-545 Diaphragm Motor Valves. Specification Sheet No. 415-1 describes maker's "Series 362" air-operated diaphragm motor valves for use with either narrow throttling band or on-off instruments. Includes construction, body materials, connections, pressure-drop ratings, etc.—Station 40, Brown Instrument Div., Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Phila. 44, Penna.

T-546 Color, Reflectance, and Gloss Standards. Bulletin describes maker's porcelain-enamel color standards for color-difference meters and reflectometers.—Henry A. Gardner Laboratory, Inc., 4723 Elm St., Bethesda, Md.

T-547 Oil Separator. Catalog C-51 describes maker's Model 40081 oil separator for pneumatic instrument systems. Includes dimensions and performance.—Genisco, Inc., 2233 Federal Ave., Los Angeles, Calif.

T-548 Facilities Brochure. Brochure describes maker's facilities and organization. Includes biographical sketches of staff and description of products—instruments, control-devices, and camera equipment.—Industrial Division, DeJUR-Amsco Corp., Northern Blvd. at 45th St., Long Island City 1, N. Y.

T-549 Custom-built Equipment. Brochure describes design and engineering services available for custom-built electronic, electric, and mechanical equipment for industry and ordnance.—Buck Engineering Co., Inc., 37-41 Marcy St., Freehold, N. J.

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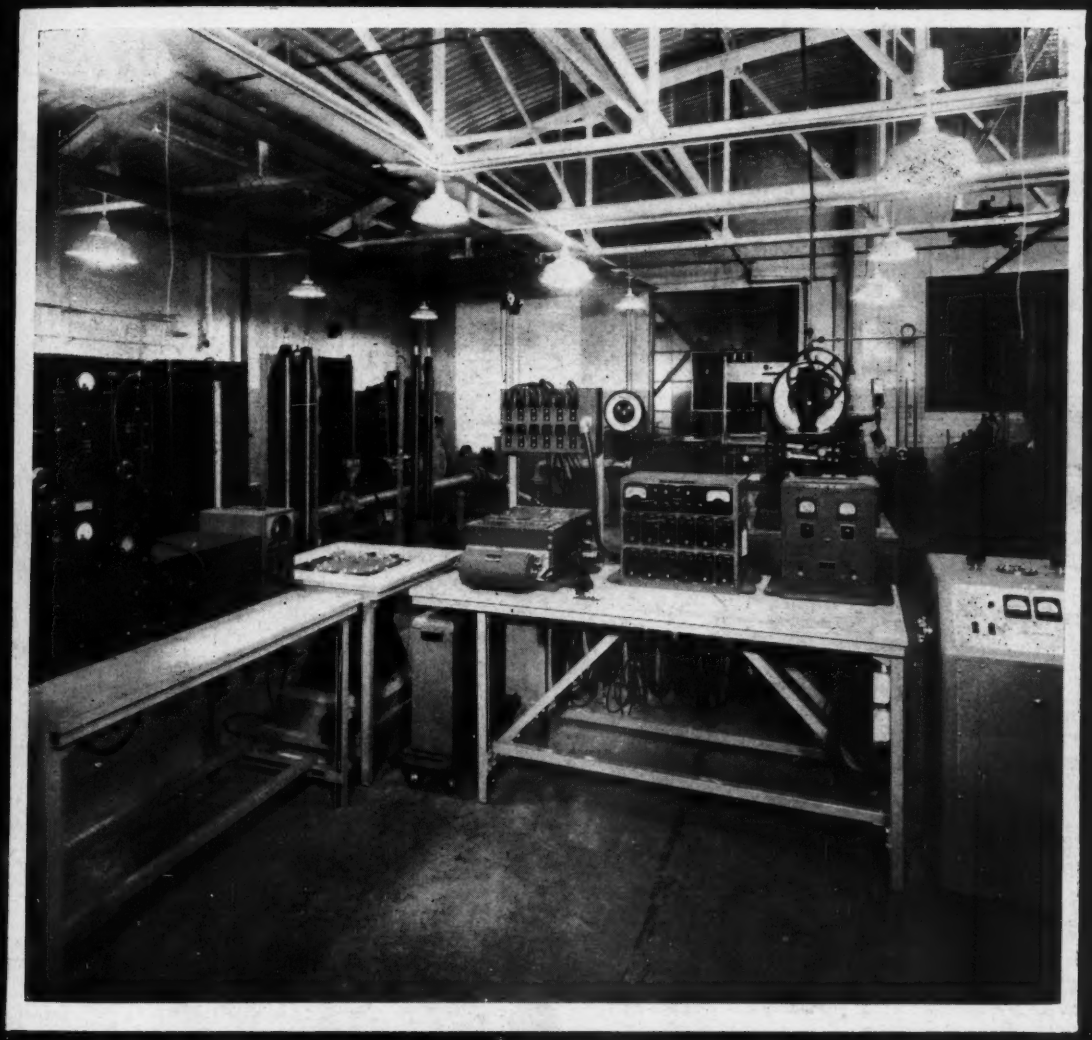

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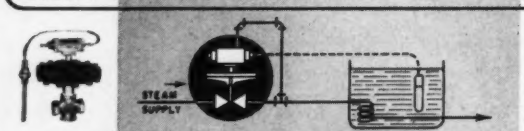

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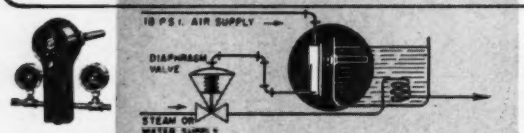

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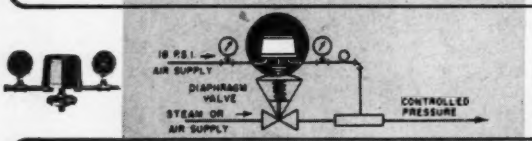

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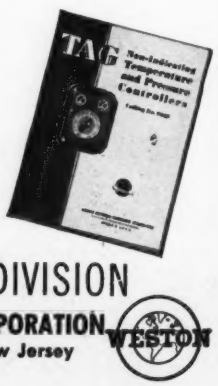

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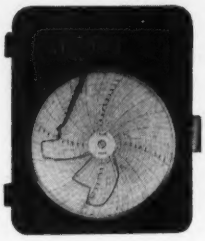

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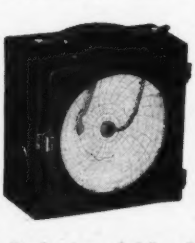

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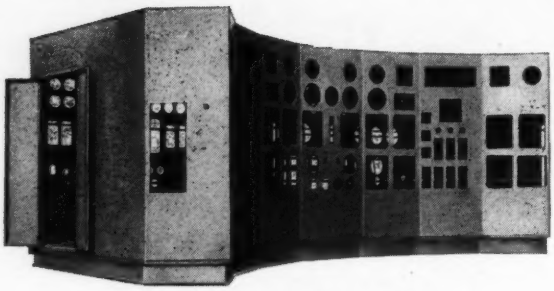

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Measurement of Flow of Fluids through Orifice Meters (Part II) 975
By William L. Cowan

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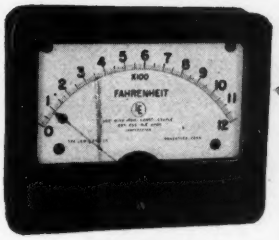

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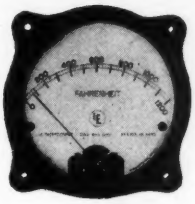

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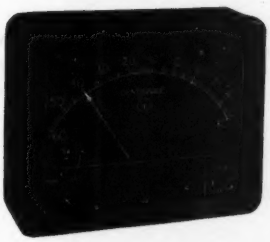

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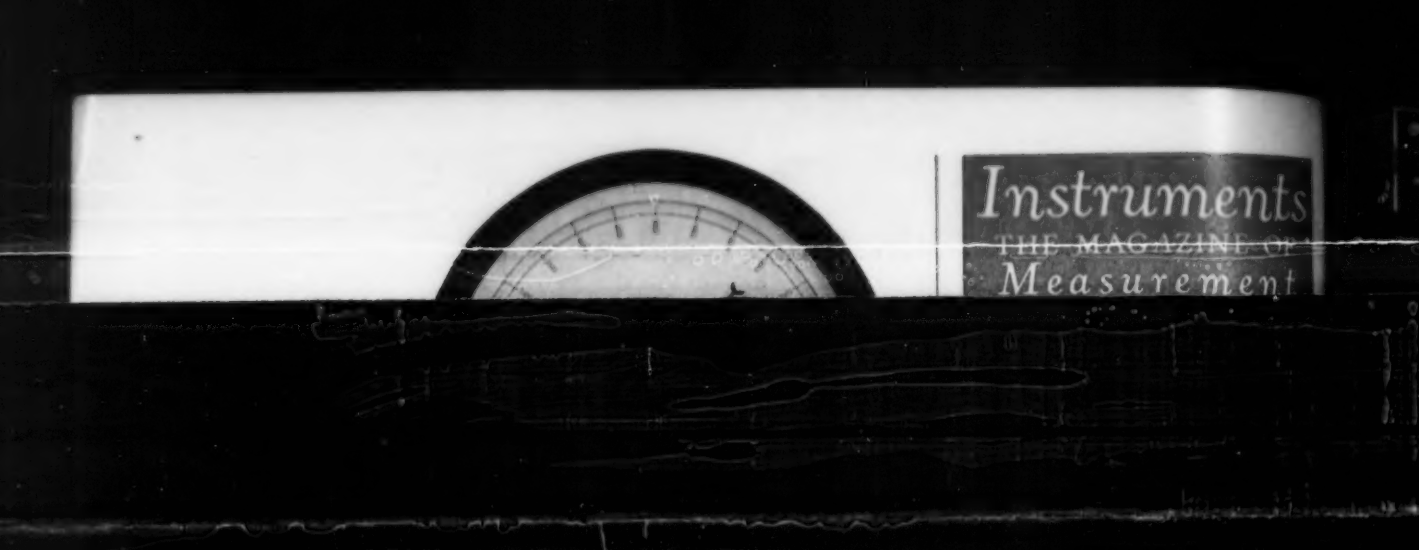
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